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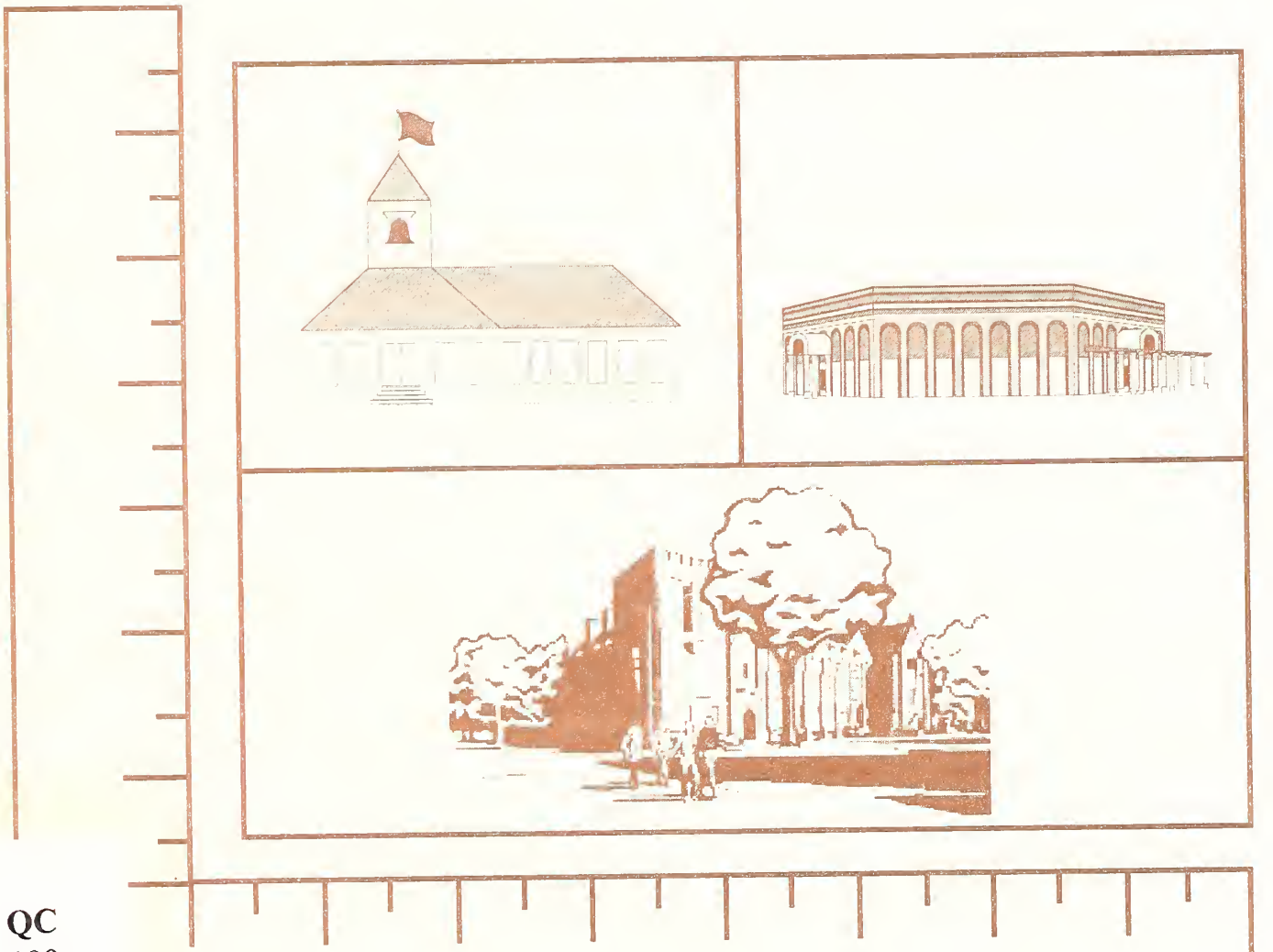
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Office of Applied Economics
Building and Fire Research Laboratory
Gaithersburg, Maryland 20899

An Approach for Measuring Reductions in Operations, Maintenance, and Energy Costs for Educational Facilities

Robert E. Chapman



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Sponsored by:
National Institute of Standards and Technology
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and

Subcommittee on Construction and Building
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National Science and Technology Council
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Abstract

The Construction and Building Subcommittee of the National Science and Technology Council is developing baseline measures of current construction industry practices and measures of progress with respect to each of the seven National Construction Goals. The seven National Construction Goals are concerned with: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries. This report provides a detailed set of baseline measures for National Construction Goal 2 (reductions in operations, maintenance, and energy costs) for educational facilities. As such, it describes data sources, data classifications, and the metrics used to develop the baseline measures. Extensive use of charts and tables is made throughout this document to illustrate the process by which the baseline measures were developed.

Keywords

building economics; construction; costs; economic analysis; educational facilities; energy costs; maintenance costs; metrics; operations costs

Preface

This study was conducted by the Office of Applied Economics in the Building and Fire Research Laboratory (BFRL) at the National Institute of Standards and Technology (NIST). The study was sponsored by the Construction and Building Subcommittee of the National Science and Technology Council. The BFRL project, of which this study is a part, seeks to develop baseline measures and measures of progress with respect to each of the seven National Construction Goals. These measures are to be disseminated both through publications and, ultimately, electronically via the World Wide Web. The intended audience for this report is the Construction and Building Subcommittee member organizations as well as construction industry representatives and other interested parties.

Acknowledgments

The author wishes to thank all those who contributed so many excellent ideas and suggestions that he has attempted to incorporate into this report. The author wishes to thank Dr. Jack E. Snell and Mr. John Talbott, Co-Chairs of the Construction and Building Subcommittee, and Dr. Andrew J. Fowell, Secretariat of the Construction and Building Subcommittee, for their guidance, suggestions, and support. Special appreciation is extended to Drs. Harold E. Marshall and Sieglinde K. Fuller of the Office of Applied Economics at NIST's Building and Fire Research Laboratory (BFRL) for the thoroughness of their reviews and for their many insights and to Ms. Catherine Linthicum and Mrs. J'aime Maynard for their assistance in preparing the manuscript for review and publication. Special appreciation is also extended to Messrs. Karthy Kasi and Daniel Cardy, formerly with BFRL's Office of Applied Economics, who helped immensely with the data collection and analysis effort during their summer internships. Thanks are also due to Ms. Christine Izzo of BFRL's Office of Applied Economics for her comments on the earlier drafts of this report and for her assistance in interpreting the results of the data analysis effort.

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List of Acronyms

Acronym	Definition
APPA	The Association of Higher Education Facilities Officers
AS&U	American School and University
ASTM	American Society for Testing and Materials
BFRL	Building and Fire Research Laboratory
C&B	Construction and Building
CBECS	Commercial Building Energy Consumption Survey
CEFPI	Council of Educational Facility Planners, International
DOE	Department of Energy
EIA	Energy Information Administration
ERIC	Educational Resource Information Center
FTE	Full-Time Equivalent
HVAC	Heating, Ventilation, and Air Conditioning
NCEF	National Clearinghouse for Educational Facilities
NCG	National Construction Goal
NIBS	National Institute of Building Sciences
OM&E	Operations, Maintenance, and Energy
RD&D	Research, Development, and Deployment

Executive Summary

The National Science and Technology Council, a cabinet-level group chaired by the President, is charged with setting federal technology policy and coordinating R&D strategies across a broad cross-section of public and private interests. It has established nine research and development committees, including the Committee on Technology (CT), to collaborate with the private sector in developing a comprehensive national technology policy. The purpose of CT is to enhance the international competitiveness of US industry through federal technology policies and programs. The Construction and Building Subcommittee of CT coordinates and defines priorities for federal research, development, and deployment related to the industries that produce, operate, and maintain constructed facilities, including buildings and infrastructure.

The mission of the Construction and Building Subcommittee is to enhance the competitiveness of the US industry, public safety, and environmental quality through research and development, in cooperation with US industry, labor, and academia, for improvement of the life cycle performance of constructed facilities. To accomplish its mission, the Construction and Building Subcommittee has established seven National Construction Goals in collaboration with a broad cross section of the construction industry.

Data describing current practices of the US construction industry are needed to establish baselines against which the industry can measure its progress towards achieving the seven National Construction Goals. The Goals are: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries. Baseline measures and measures of progress will be produced for each National Construction Goal in each of the four key construction industry sectors. The four sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works.

This document provides a detailed set of baseline measures for National Construction Goal 2 (reductions in operations, maintenance, and energy costs) for educational facilities. Industry performance in 1994 is used as the reference point from which the values of the baseline measures are calculated. Goal 2 was identified as one of the highest priority National Construction Goals by the construction industry.

This document has five chapters. Chapter 1 explains the purpose, scope, and general approach. Chapter 2 introduces the National Construction Goals, describes how a well-defined set of metrics is used to develop the baseline measures, and outlines the project approach. Chapter 3 provides an overview of the construction industry. The overview provides the context within which the baseline measures are developed. Chapter 4

presents the baseline measures. Chapter 5 concludes the document with a summary and suggestions for further research.

Chapter 2 provides perspective on the overall effort to develop baseline measures for each of the seven National Construction Goals. First, each National Construction Goal is introduced and described. Next, the process for developing baseline measures for each Goal is described. This process involves: (1) specifying data relationships; (2) collecting and compiling the key data and supporting information for the base year, 1994; (3) defining metrics for each goal/sector combination; and (4) producing the metrics in a summary form (i.e., figures and tables to depict the metrics). Criteria are then presented which ensure that the data selected for *analysis* are well defined, consistent, and replicable. The chapter also outlines a strategy for using the baseline measures to drive performance improvement.

Chapter 3 provides a snapshot of the US construction industry. It provides the context within which the baseline measures are developed. An extensive set of statistics has been compiled on each sector; many of these statistics are included in Chapter 3. These statistics are useful not only as a tool for defining the baseline measures but also as a resource reference for readers with a wide variety of interests in the construction industry.

Information is first presented on the value of construction put in place to show the size of the construction industry and each of its four sectors. The four sectors are residential, commercial/institutional, industrial, and public works. Information on the commercial/ institutional sector is then presented to focus on its importance within the overall construction industry and to define its key components. Educational facilities are shown to be a key component of the commercial/institutional sector. Special emphasis is then placed on detailing the key characteristics of educational facilities (e.g., building floorspace and year of construction). Detailing the key characteristics of educational facilities is crucial because investments in these facilities affect not only new construction activities, but additions and alterations and maintenance and repair activities as well.

The construction industry is a key component of the US economy. A key indicator of construction activity is the value of construction put in place. Data published by the US Bureau of the Census are used to establish the composition of construction expenditures by type of construction. These expenditures are then assigned to one of the four key construction industry sectors.

Table ES-1 summarizes both the annual sector totals and the sum total. Since 1994, the value of construction put in place has risen from $571.3 billion in 1994 to $734.3 billion in 2000 in constant 1997 dollars. The largest component of construction over this period was in the residential sector (about 45 percent of the total), with the smallest component in the industrial sector (about 6 percent).

Table ES-1. Value of Construction Put in Place in Millions of 1997 Dollars: Sector Totals and Sum Total

Sector	Value of Construction Put in Place ($ Millions)						
	1994	1995	1996	1997	1998	1999	2000
Residential	266,876	266,089	295,555	294,244	311,248	331,705	341,738
Commercial/ Institutional	152,521	165,828	184,237	205,703	215,774	221,308	233,329
Industrial	33,440	37,511	38,844	37,738	40,393	33,521	29,925
Public Works	118,434	117,111	115,034	118,944	125,459	128,671	129,280
Total - All Sectors	571,271	586,539	633,670	656,629	692,874	715,205	734,272

Source: US Bureau of the Census.

Chapter 4 presents the baseline measures. These measures are based on data published by four sources: (1) the Energy Information Administration (EIA), a part of the US Department of Energy (DOE); (2) the Association of Higher Education Facilities Officers (APPA); (3) the American School & University (AS&U) Magazine; and (4) Whitestone Research. Section 4.1 describes each of the data sets. The baseline measures are reported and described in Section 4.2. Section 4.2.1 covers K-12 facilities. Section 4.2.2 covers college and university facilities. Section 4.2.3 uses data from the EIA's Commercial Buildings Energy Consumption Survey (CBECS) to establish the national average energy cost per unit of floor area and the rates of utilization of energy conserving features and practices. The chapter concludes with a summary of the various baseline measures for operations, maintenance, and energy (OM&E) costs for educational facilities.

Because the OM&E baseline measures presented in Chapter 4 are drawn from several key documents, a comprehensive list of OM&E cost components are identified and defined. These components include the following:

- **administration** - includes all administrative costs for the facility including payroll costs, equipment, supplies, communications, computer rental, accounting costs, and training costs
- **work control** - includes all costs necessary for the proper planning, scheduling, and dispatching of maintenance work, including payroll, database maintenance, supervision, and cost estimation
- **engineering/architecture** - includes all design and engineering costs
- **project management** - includes all costs associated with actual estimating, contracting, inspecting, and final approval of new or renovated construction
- **building maintenance** - includes in-house and contracted services for routine repairs, minor corrective maintenance, preventive maintenance and service calls for HVAC, plumbing, electrical, painting, glazing, and elevators

- **custodial maintenance** - includes interior and exterior functions such as window and building cleaning, snow removal, and operating costs such as towels
- **grounds maintenance** - includes landscaping and grounds maintenance costs for parking areas, irrigation systems, and fencing
- **utilities operations** - includes all costs for heating, cooling, lighting, and other utilities for physical plant operations, excluding cost of fuel and purchased utilities
- **solid waste disposal** - includes all costs associated with refuse removal
- **hazardous waste disposal** - includes all costs associated with hazardous waste removal
- **security** - includes all security expenses such as traffic, parking, and building security

Table ES-2 summarizes the baseline measures for educational facilities that are presented in Sections 4.2.1, 4.2.2, and 4.2.3 of this document. The table is organized to serve as a quick reference; it includes a brief description of each measure, the year for the data, the value of the measure in dollars per square meter ($/m^2$) and dollars per square foot($/ft^2$), and the source of the data. Two sets of summary OM&E measures are presented first—one for K-12 facilities and one for college and university facilities—followed by a more detailed set of measures.

Chapter 5 discusses additional areas of research that might be of value to government agencies and private bodies who are concerned about reducing operations, maintenance, and energy costs in educational facilities. These areas of research are concerned with: (1) the dissemination of more detailed information on building characteristics and energy consumption by EIA that would facilitate the construction of measures for K-12 facilities and for college and university facilities rather than general measures for educational facilities as a whole; and (2) the measurement and evaluation of progress toward achievement of National Construction Goals 2 in educational facilities.

Table ES-2. Summary of OM&E Baseline Measures for Educational Facilities

DESCRIPTION	YEAR	BASELINE	SOURCE
OM&E: K-12 Facilities	1996	$35.74 /$m^2$ ($3.32 /$ft^2$)	AS&U
OM&E: College & University Facilities	1996	$37.78 /$m^2$ ($3.51 /$ft^2$)	AS&U
Average Custodial (Cleaning) Cost	1993-1994	$9.81 /$m^2$ ($0.91 /$ft^2$)	APPA
Average Grounds Cost	1993-1994	$2.96 /$m^2$ ($0.28 /$ft^2$)	APPA
Average Solid Waste Disposal Cost	1993-1994	$0.56 /$m^2$ ($0.05 /$ft^2$)	APPA
Average Hazardous Waste Disposal Cost	1993-1994	$0.40 /$m^2$ ($0.04 /$ft^2$)	APPA
Average Security Cost	1993-1994	$3.81 /$m^2$ ($0.35 /$ft^2$)	APPA
Average Building Maintenance Cost	1993-1994	$9.63 /$m^2$ ($0.90 /$ft^2$)	APPA
Average Electricity Cost	1993-1994	$10.61 /$m^2$ ($0.99 /$ft^2$)	APPA
Average Gas Cost	1993-1994	$3.54 /$m^2$ ($0.33 /$ft^2$)	APPA
Average Water and Sewer Cost	1993-1994	$0.43 /$m^2$ ($0.04 /$ft^2$)	APPA
Sum of Major Fuel Expenditures: All Educational Facilities	1995	$9.90 /$m^2$ ($0.92 /$ft^2$)	CBECS

1. Introduction

1.1 Background

The National Science and Technology Council, a cabinet-level group chaired by the President, is charged with setting federal technology policy and coordinating R&D strategies across a broad cross-section of public and private interests. It has established nine research and development committees, including the Committee Technology (CT), to collaborate with the private sector in developing a comprehensive national technology policy. The purpose of CT is to enhance the international competitiveness of US industry through federal technology policies and programs. The Construction and Building Subcommittee of CT coordinates and defines priorities for federal research, development, and deployment related to the industries that produce, operate, and maintain constructed facilities, including buildings and infrastructure.[1]

The mission of the Construction and Building Subcommittee is to enhance the competitiveness of US industry, public safety, and environmental quality through research and development, in cooperation with US industry, labor, and academia, for improvement of the life cycle performance of constructed facilities. To accomplish its mission, the Construction and Building Subcommittee has established seven National Construction Goals in collaboration with a broad cross section of the construction industry.[2]

Data describing current practices of the US construction industry are needed to establish baselines against which industry can measure its progress towards achieving the seven National Construction Goals. The seven National Construction Goals are concerned with: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries.

Although information having relevance to the seven goals is available, for the most part, this information has such a narrow focus that a consistent set of baseline measures and associated measures of progress cannot be produced without first conducting a significant research effort. Specifically, information from a wide variety of data sets needs to be collected, reviewed, analyzed, and critiqued to ensure that the baseline measures and measures of progress which result are:

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[1] Wright, Richard N. 1995. "Government and Industry Working Together." *Construction Business Review* (January/February): pp. 44-49.

[2] Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1995. *Construction and Building: Federal Research and Development in Support of the US Construction Industry.* Washington, DC: National Science and Technology Council.

(1) adequate (i.e., they not only capture the complexities of the US construction industry, but also represent a consensus among experts in the field); and

(2) suitable for dissemination to the public.

It is essential to have baseline data and associated measures of progress to determine the success of actions taken to improve the competitiveness of the US construction industry. In addition, baselines and measures of progress will make it possible to demonstrate the benefits of advanced technologies and practices, and to guide decision makers in prioritizing potential programs.

The goal of this project is to develop a suite of products that support the measurement and attainment of the National Construction Goals by the four key construction industry sectors. The four industry sectors are: (1) residential; (2) commercial/institutional; (3) industrial; and (4) public works. Three basic sets of products are envisioned:

(1) *Baseline Measures*: Develop baseline measures that characterize current industry performance with respect to each of the seven goals. The averages of current practice (defined in this document as industry performance in 1994) will become the baselines for measuring progress towards achieving each of the goals.

(2) *Measures of Progress*: Develop methods for measuring progress. These "results" measures are envisioned as a composite of performance measures offering a means not only for monitoring actual performance, but also for marshaling support for improving results.

(3) *Periodic Reports*: Provide information on each of the seven goals. This information will be made available to interested parties both through publications and, ultimately, electronically via the World Wide Web.

1.2 Purpose

The purpose of this document is to provide a detailed set of baseline measures for National Construction Goal 2 (reductions in operations, maintenance, and energy costs) for educational facilities. As such, it describes data sources, data classifications, and the metrics used to develop the baseline measures. Extensive use of charts and tables is made throughout this document to illustrate the process by which the baseline measures were developed. The focus of this document is on educational facilities. Readers wishing a comprehensive set of baseline measures for each sector of the construction industry are referred to a companion document.[3]

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[3] Chapman, Robert E., and Roderick Rennison. 1998. *An Approach for Measuring Reductions in Operations, Maintenance, and Energy Costs: Baseline Measures of Construction Industry Practices for the National Construction Goals*. NISTIR 6185, Gaithersburg, MD: National Institute of Standards and Technology.

The intended audience for this document is the Construction and Building Subcommittee member organizations,[4] four private sector organizations with interest in specific building sectors,[5] designers and managers of educational facilities, construction industry representatives, and other interested parties. In addition, because this document includes both detailed information on the baseline measures for National Construction Goal 2 and a compilation of statistics on the four sectors and the construction industry as a whole, it is anticipated that this document will serve as a resource reference for readers with a wide variety of interests in the construction industry.

1.3 Scope and Approach

This document has four chapters in addition to the Introduction. Chapter 2 introduces the National Construction Goals and describes how a well-defined set of metrics is used to develop the baseline measures. Chapter 3 provides an overview of the construction industry. The overview provides the context within which the baseline measures are developed. Chapter 4 presents the baseline measures for educational facilities. Key baseline measures are summarized in Table 4-7, which appears at the end of Chapter 4. Chapter 5 concludes the document with a summary and suggestions for further research.

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[4] The following Federal Agencies are members of the Construction and Building Subcommittee: Department of Agriculture, Department of Commerce, Department of Defense, Department of Education, Department of Energy, Department of Health and Human Services, Department of Housing and Urban Development, Department of Interior, Department of Labor, Department of Transportation, Department of Veterans Affairs, Environmental Protection Agency, General Services Administration, National Aeronautics and Space Administration, and National Science Foundation.

[5] The four private sector organizations are: (1) National Association of Home Builders Research Center (residential); (2) National Institute of Building Sciences (commercial/institutional); (3) Construction Industry Institute (industrial); and (4) American Public Works Association (public works).

2. The National Construction Goals: A Tool for Promoting Competitiveness Within the Construction Industry

2.1 Description of the National Construction Goals

The Construction and Building (C&B) Subcommittee has studied research priorities expressed by the construction industry. These priorities translate into the following seven National Construction Goals:

1. 50 % Reduction in Delivery Time
2. 50 % Reduction in Operation, Maintenance, and Energy Costs
3. 30 % Increase in Productivity and Comfort
4. 50 % Fewer Occupant-Related Illnesses and Injuries
5. 50 % Less Waste and Pollution
6. 50 % More Durability and Flexibility
7. 50 % Reduction in Construction Worker Illnesses and Injuries

To make the National Construction Goals operational, they are based on the values of a well-defined set of baseline measures. The values of the baseline measures for each goal are averages of industry performance in 1994. The year 1994 was established as the basis for computing the values of the baseline measures because it was the year when the National Construction Goals were first formulated.[6]

Two priority thrusts—better constructed facilities, and improved health and safety of the construction work force—were defined as the focus of C&B-related research, development, and deployment (RD&D) activities. The objective of the C&B-related RD&D activities is to make technologies and practices capable of achieving the goals under the two priority thrusts available for general use in the construction industry by 2003.

Achievement of the National Construction Goals will: (1) reduce the first costs and life-cycle costs of constructed facilities in the four key construction industry sectors (i.e., residential, commercial/institutional, industrial, and public works); (2) result in better constructed facilities; and (3) result in improved health and safety for both construction workers and occupants of constructed facilities. Achievement of the goals will convey benefits to each of the four construction industry sectors (e.g., housing will become more affordable through reductions in first costs and life-cycle costs). However, depending on the goal and the construction industry sector, the beneficial impacts are expected to vary. To gain a better appreciation of the importance of the National Construction Goals, both individually, and taken together, and of their relationship to the four key construction

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[6] Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1994. *Rationale and Preliminary Plan for Federal Research for Construction and Building*. NISTIR 5536. Washington, DC: National Science and Technology Council.

industry sectors, a brief description of each goal follows. The descriptions are patterned after those given in the report by Wright, Rosenfeld, and Fowell.[7]

Goal 1: 50 % Reduction in Delivery Time

Delivery time is defined as the elapsed time from the decision to construct a new facility until its readiness for service. Delivery time issues affect both industrial competitiveness and project costs. During the initial planning, design, procurement, construction, and start-up process, the needs of the client are not being met. Furthermore, the client's needs evolve over time, so a facility long in delivery may be uncompetitive or unsuitable when it is finished. Delays almost always translate into increased project costs due to inflationary effects, higher financial holding costs, and reduced productivity. Furthermore, the investments in producing the facility cannot be recouped until the facility is operational. Owners, users, designers, and constructors are among the groups calling for technologies and practices to reduce delivery time.

Goal 2: 50 % Reduction in Operations, Maintenance, and Energy Costs

Operations, maintenance, and energy (OM&E) costs are a major factor in the life-cycle costs of a constructed facility. In some cases, OM&E costs over the life of a facility exceed its first cost. However, because reductions in OM&E costs are often associated with increased first costs, facility owners and managers may under-invest in cost saving technologies. Furthermore, undue attention on minimizing first costs may result in a facility which is expensive to operate and maintain, wastes energy resources, is inflexible, and rapidly becomes obsolete. Finally, because OM&E costs tend to increase more rapidly than the general rate of inflation, facility owners and operators are often forced to reallocate funds to cover OM&E costs. Reductions in OM&E costs will produce two types of benefits. First, constructed facilities will become more affordable because facility owners and operators are making more cost-effective choices among investments (e.g., design configurations) which affect life-cycle costs. Second, these same facilities will better conserve scarce energy resources.

Goal 3: 30 % Increase in Productivity and Comfort

Industry and government studies have shown that the annual salary costs of the occupants of a commercial or institutional building are of the same order of magnitude as the capital cost of the building.[8] Occupant comfort depends largely on the nature of buildings, building furnishings, and indoor environments. The quality of indoor environments also has a large impact on occupant health and productivity. Improvement of the productivity of the occupants (or for an industrial facility, improvement of the productivity of the

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[7] Wright, Richard N., Arthur H. Rosenfeld, and Andrew J. Fowell. 1995. *Construction and Building: Federal Research and Development in Support of the US Construction Industry*. Washington, DC: National Science and Technology Council.

[8] Building Owners and Managers Association. 1994. *Experience Exchange Report, National Cross-Tabulations, 1994*. Washington, DC: Building Owners and Managers Association.

process housed by the facility) is an important performance characteristic for most constructed facilities.

Goal 4: 50 % Fewer Occupant-Related Illnesses and Injuries

Buildings are intended to shelter and support human activities, yet the environment and performance of buildings can contribute to illnesses and injuries for building users. Examples are avoidable injuries caused by fire, natural hazards, slips, and falls; disease from airborne microbes, often associated with a workplace environment; and building damage or collapse from fire, earthquakes, or extreme winds. Reductions in illnesses and injuries will increase building users' productivity as well as reduce the costs of medical care and litigation.

Goal 5: 50 % Less Waste and Pollution

Improvement of the performance of constructed facilities provides major opportunities to reduce waste and pollution at every step of the delivery process, from raw material extraction to final demolition and recycling of the facility and its contents. Additional reductions come from reduced energy use, reduced water consumption, and reductions in waste water production, which are considered in part by Goal 2.

Goal 6: 50 % More Durability and Flexibility

Durability denotes the capability of the constructed facility to continue (given appropriate maintenance) its initial performance over the intended service life. Flexibility denotes the capability to adapt the constructed facility to changes in use or users' needs. Increased durability and flexibility of constructed facilities reduces life-cycle costs and prolongs the economic life of the facility (i.e., the period of time over which an investment in the original facility is considered to be the least-cost alternative for meeting a particular objective).

Goal 7: 50 % Reduction in Construction Worker Illnesses and Injuries

Health and safety issues exert a major effect on the competitiveness of the US construction industry. Construction workers die as a result of work-related trauma at a rate which is higher than all other industries except mining and agriculture. Construction workers also experience a higher incidence of nonfatal injuries resulting in days away from work than workers in other industries do. Although the construction workforce represents less than 6 % of the nation's work force, it is estimated that the construction industry pays about 15 % of the nation's workers' compensation.[9]

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[9] The Center to Protect Workers' Rights. 1997. *The Construction Chart Book: The US Construction Industry and Its Workers*. Report D1-97. Washington, DC: The Center to Protect Workers' Rights.

2.2 Baseline Measures

As noted earlier, the baseline measures for each goal are averages of industry performance in 1994. Thus, with regard to the baseline measures, 1994 is the "base year." Consequently, data from 1994 drive the data collection effort culminating with the development of the baseline measures for each National Construction Goal.

The process for developing baseline measures used in this project involves: (1) specifying data relationships; (2) collecting and compiling the key data and supporting information for the base year, 1994;[10] (3) defining metrics for each goal/sector combination; and (4) producing the metrics in a tabular summary form and, where appropriate, producing charts and graphs to depict the metrics. If the goal/sector combination has components and subcomponents, then metrics are defined for each. This process is employed because the metrics represent not only a statement of current construction industry performance, but tools for measuring an individual organization's performance as well. By providing a small set of well-defined metrics, individual organizations can construct their own performance baselines. For example, individual organizations can see how a collection of their projects performs vis-à-vis the "national" data. To summarize, the basic philosophy behind the baseline measures is that they are not a static tool whose sole purpose is quantifying the value of the goal, but a means for driving performance improvement within individual organizations.

Criteria are needed to ensure that the data selected for *analysis* are well-defined, consistent, and replicable. Because data are so important to the baseline measures for each goal, BFRL reviewed many potential sources (e.g., journals, technical publications, and electronic media) of baseline-related data/information. This review suggested three criteria which must be met by any data in order to be accepted for analysis. These criteria are:

(1) Published by a reliable, nationally-recognized organization and available to the public;

(2) Updated on a regular basis; and

(3) Able to be normalized to account for changes in the building stock and the level of construction activity.

2.3 How This Document Helps

This document is part of a series. As such, it provides perspective on the overall effort to develop baseline measures and measures of progress for each of the seven National

[10] If data are available for years in addition to 1994, then these data are collected at the same time as the base year data and used to illustrate trends; these data are also used to compute the associated measures of progress.

Construction Goals.[11] It also serves to highlight how these measures and their associated metrics can be used to drive performance improvement.

On a deeper level, this document provides step-by-step descriptions of how to construct a well-defined set of baseline measures, their components, and associated metrics for the specific goal of reducing operations, maintenance, and energy costs for educational facilities. Information on data classification, data sources, and data collection and analysis provide the underpinnings for the results presented in this document. It is anticipated that once users of this document have understood the vital role of metrics as a process improvement tool, they will see how the National Construction Goals will benefit both their organization and the US construction industry.

[11] Three earlier companion documents focused on National Construction Goals 1, 2, and 7. For information on reductions in delivery time (Goal 1), see Chapman, Robert E., and Roderick Rennison. 1998. *An Approach for Measuring Reductions in Delivery Time: Baseline Measures of Construction Industry Practices for the National Construction Goals.* NISTIR 6189. Gaithersburg, MD: National Institute of Standards and Technology. For information on reductions in operations, maintenance, and energy costs (Goal 2), see Chapman, Robert E., and Roderick Rennison. 1998. *An Approach for Measuring Reductions in Operations, Maintenance, and Energy Costs: Baseline Measures of Construction Industry Practice for the National Construction Goals.* NISTIR 6185 . Gaithersburg, MD: National Institute of Standards and Technology. For information on reductions in construction worker illnesses and injuries (Goal 7), see Chapman, Robert E. 2000. *An Approach for Measuring Reductions in Construction Worker Illnesses and Injuries: Baseline Measures of Construction Industry Practices for the National Construction Goals.* NISTIR 6473. Gaithersburg, MD: National Institute of Standards and Technology.

3. Overview of the Construction Industry

The construction industry is a key component of the US economy and is vital to its continued growth. Investment in plant and facilities, in the form of construction activity, provides the basis for the production of products and the delivery of services. Investment in infrastructure promotes the smooth flow of goods and services and the movement of individuals. Investment in housing accommodates new households and allows existing households to expand or improve their housing. Clearly, construction activities affect nearly every aspect of the US economy.[12]

This chapter provides a snapshot of the US construction industry. The chapter contains three sections. Each section deals with a particular topic. The topics progress from general in nature to very specific, as described below.

Section 3.1 presents information on the value of construction put in place to show the size of the construction industry and each of its four sectors. The four sectors, which taken together define the construction industry, are residential, commercial/institutional, industrial, and public works. Data from the past seven years (i.e., 1994 through 2000) are used to highlight the magnitude of construction-related investments in each sector. Data from 1997 are then used to establish the relative shares of construction-related investments for each sector.

Section 3.2 uses information on the commercial/institutional sector *both* to focus on its importance within the overall construction industry *and* to define its key components. Information on investment activity, the number of commercial/institutional buildings, and the amount of commercial/institutional floorspace is used to identify both those characteristics that are changing and those that are remaining constant. Educational facilities are a key component of the commercial/institutional sector. Information showing the relative share of construction-related investments in educational facilities vis-à-vis the other components of the commercial/institutional sector is also presented.

Section 3.3 places special emphasis on identifying and detailing the key characteristics of educational facilities. Information detailing key characteristics of educational facilities (e.g., building floorspace and year of construction) is crucial because investments in these facilities affect not only new construction activities, but additions and alterations and maintenance and repair activities as well.

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[12] Readers interested in learning more about construction statistics, their sources and interpretation, are referred to the document by Rogers (Rogers, R. Mark. 1994. *Handbook of Key Economic Indicators*. Burr Ridge, IL: Irwin Professional Publishing).

3.1 Value of Construction Put in Place

This section provides information on a key indicator of construction activity—the value of construction put in place. Data published by the US Bureau of the Census are used to establish the composition of construction expenditures by type of construction/function (e.g., non-residential/office building). These expenditures are then assigned to the four key construction industry sectors. The reference document used throughout this section is the Current Construction Reports series C30 publication Value of Construction Put in Place.[13] A brief description of the "C30 report" follows. Special attention is given to the organization of the data in the C30 report and how these data map into the four key construction industry sectors. The section concludes with tabular and graphical summaries of the value of construction put in place.

Construction expenditures data are published monthly in the Current Construction Reports series C30 publication Value of Construction Put in Place. Construction expenditures refer to actual construction rather than planned or just initiated activity. It is noteworthy that the C30 report covers both private residential and non-residential construction activities and public sector construction activities.

The value of construction put in place is a measure of the value of construction installed or erected at a site during a given period. For an individual project, this includes: (1) cost of materials installed or erected; (2) cost of labor and a proportionate share of construction equipment rental; (3) contractor's profit; (4) cost of architectural and engineering work; (5) miscellaneous overhead and office costs chargeable to the project on the owner's books; and (6) interest and taxes paid during construction. Expenses do not include the cost of land nor do they include maintenance and repairs to existing structures or service facilities.

The C30 data are compiled via survey and through indirect estimation. In the context of the C30 survey, construction includes the following: (1) new buildings and structures; (2) additions, alterations, conversions, expansions, reconstruction, renovations, rehabilitations, and major replacements (e.g., the complete replacement of a roof or a heating system); (3) mechanical and electrical installations (e.g., plumbing, heating, electrical work, and other similar building services); (4) site preparation and outside construction of fixed structures or facilities (e.g., sidewalks, highways and streets, water supply lines, sewers, and similar facilities which are built into or fixed to the land); (5) installation of boilers, overhead hoists and cranes, and blast furnaces; (6) fixed, largely site-fabricated equipment not housed in a building (e.g., petroleum refineries and chemical plants); and (7) cost and installation of construction materials placed inside a building and used to support production machinery (e.g., concrete platforms, overhead steel girders, and pipes).

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[13] US Department of Commerce. 2001. *Current Construction Reports: Value of Construction Put in Place. C30.* Washington, DC: US Bureau of the Census.

The data presented in the C30 report are summarized in Tables 3-1 and 3-2. To facilitate comparisons between this report and the C30 report, Tables 3-1 and 3-2 use the same row and column headings as are used in the C30 report.

Tables 3-1 and 3-2 record annual values for the years 1994 through 2000. Table 3-1 records annual values in millions of constant 1997 dollars. Table 3-2 records annual values in millions of current dollars.[14] Reference to Table 3-1 reveals that total construction expenditures in real terms have increased modestly over the seven-year period (i.e., from $571.3 billion to $734.3 billion). When the effects of inflation are included, the rate of increase is more pronounced. Table 3-2 shows total construction expenditures in current dollars.

Tables 3-1 and 3-2 are organized to allow for in-depth analyses of the components/ subcomponents of total construction expenditures. To facilitate such analyses, the data presented in Tables 3-1 and 3-2 are initially divided into two parts: (1) private construction; and (2) public construction.

Private construction contains two major components--residential buildings and non-residential buildings--plus a number of subcomponents. Both the two major components and the various subcomponents are shown as headings in the first column of Tables 3-1 and 3-2.

The residential buildings component includes new private housing and improvements. New private housing includes new houses, apartments, condominiums, and town houses. New private housing units are classified as "1 unit" or "2 or more units." The value of improvements put in place are a direct measure of the value of residential additions and alterations activities.

The non-residential buildings component includes industrial, office buildings, hotels and motels, and "other commercial" (e.g., shopping centers, banks, service stations, warehouses, and other categories). Also falling under the non-residential buildings component are religious, educational, hospital and institutional, and "miscellaneous" non-residential buildings.

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[14] Inflation reduces the purchasing power of the dollar over time; deflation increases it. When amounts are stated in actual prices as of the year in which they occur, they are said to be in *current dollars*. Current dollars are dollars of any one year's purchasing power, inclusive of inflation/deflation. That is, they reflect changes in purchasing power of the dollar from year to year. In contrast, *constant dollars* are dollars of uniform purchasing power, exclusive of inflation/deflation. Constant dollars indicate what the same good or service would cost at different times if there were no change in the general price level to change the purchasing power of the dollar. For additional information on conducting economic analyses using either constant dollars or current dollars, see Fuller, Sieglinde K., and Stephen R. Petersen. 1996. *Life-Cycle Costing Manual for the Federal Energy Management Program*. NIST Handbook 135. Gaithersburg, MD: National Institute of Standards and Technology.

Table 3-1. Value of Construction Put in Place in Millions of Constant 1997 Dollars

Type of Construction	Millions of Constant (1997) Dollars						
	1994	1995	1996	1997	1998	1999	2000
Total Construction	**571,271**	**586,538**	**633,670**	**656,630**	**692,876**	**715,203**	**734,273**
Private Construction	**439,110**	**449,367**	**489,838**	**501,749**	**537,585**	**553,609**	**576,813**
Residential Buildings	262,659	261,129	290,341	289,014	306,260	326,447	337,030
New Housing Units	184,639	180,951	197,385	198,063	218,041	233,527	238,508
1 Unit	169,156	162,066	176,395	175,179	194,119	208,020	213,225
2 Units or more	15,483	18,885	20,991	22,883	23,922	25,507	25,282
Improvements	78,020	80,177	92,956	90,951	88,220	92,920	98,523
Nonresidential buildings	132,262	144,146	158,963	172,990	185,651	183,216	189,229
Industrial	31,829	35,919	37,409	36,739	39,410	32,655	28,881
Office	24,386	27,040	28,801	34,305	41,106	43,582	50,145
Hotel, motels	5,111	7,508	11,270	12,898	14,423	14,916	14,764
Other commercial	41,290	45,030	49,769	51,809	52,176	53,477	55,338
Religious	4,254	4,567	4,683	5,777	6,419	7,016	7,265
Educational	5,302	5,799	6,963	8,693	9,441	9,156	10,226
Hospital and institutional	13,490	11,875	12,167	13,546	13,427	12,750	13,125
Miscellaneous	6,600	6,409	7,901	9,223	9,249	9,664	9,485
Farm nonresidential	3,547	3,182	3,778	3,815	4,170	4,165	4,645
Public Utilities	37,464	37,856	34,244	33,638	38,966	37,066	43,299
Telecommunications	11,129	11,711	12,198	12,416	12,974	14,246	16,203
Other public utilities	26,335	26,145	22,047	21,222	25,992	22,820	27,095
Railroads	3,673	3,704	4,542	4,922	5,584	4,602	3,805
Electric light and power	16,403	14,832	11,579	11,325	12,053	13,155	19,010
Gas	5,161	6,629	4,877	4,006	7,124	3,669	3,377
Petroleum pipelines	1,097	981	1,048	969	1,231	1,393	903
All other private	3,178	3,054	2,511	2,292	2,537	2,715	2,611
Public Construction	**132,161**	**137,170**	**143,833**	**154,882**	**155,291**	**161,595**	**157,460**
Buildings	54,370	60,971	65,554	71,867	71,333	72,706	74,088
Housing and redevelopment	4,217	4,960	5,214	5,230	4,988	5,258	4,708
Industrial	1,611	1,592	1,435	999	983	866	1,044
Educational	22,388	27,219	29,528	34,385	35,273	37,176	39,225
Hospital	4,344	4,472	4,769	5,152	3,802	3,713	3,608
Other	21,809	22,727	24,608	26,100	26,288	25,693	25,503
Highways and streets	41,145	39,711	40,759	44,105	47,228	50,098	46,905
Military facilities	2,549	3,179	2,676	2,556	2,462	1,976	2,104
Conservation and development	6,997	6,659	6,205	5,739	5,302	5,618	5,416
Sewer systems	9,566	8,889	10,120	10,392	9,898	10,464	9,263
Water supply facilities	5,110	4,971	5,802	6,419	6,649	7,114	6,239
Miscellaneous public	12,426	12,791	12,717	13,803	12,417	13,621	13,444

Table 3-2. Value of Construction Put in Place in Millions of Current Dollars

Type of Construction	Millions of Current Dollars						
	1994	1995	1996	1997	1998	1999	2000
Total Construction	**519,539**	**555,591**	**613,535**	**656,630**	**711,759**	**764,233**	**815,414**
Private Construction	**399,346**	**425,658**	**474,273**	**501,749**	**552,236**	**591,561**	**640,554**
Residential Buildings	238,874	247,351	281,115	289,014	314,607	348,826	374,274
New Housing Units	167,919	171,404	191,113	198,063	223,983	249,536	264,864
1 Unit	153,838	153,515	170,790	175,179	199,409	222,280	236,788
2 Units or more	14,081	17,889	20,324	22,883	24,574	27,256	28,076
Improvements	70,955	75,947	90,002	90,951	90,624	99,290	109,410
Nonresidential buildings	120,285	136,541	153,912	172,990	190,711	195,776	210,140
Industrial	28,947	34,024	36,220	36,739	40,484	34,894	32,073
Office	22,178	25,613	27,886	34,305	42,226	46,570	55,686
Hotel, motels	4,648	7,112	10,912	12,898	14,816	15,939	16,396
Other commercial	37,551	42,654	48,188	51,809	53,598	57,143	61,453
Religious	3,869	4,326	4,534	5,777	6,594	7,497	8,068
Educational	4,822	5,493	6,742	8,693	9,698	9,784	11,356
Hospital and institutional	12,268	11,248	11,780	13,546	13,793	13,624	14,575
Miscellaneous	6,002	6,071	7,650	9,223	9,501	10,327	10,533
Farm nonresidential	3,226	3,014	3,658	3,815	4,284	4,451	5,158
Public Utilities	34,071	35,859	33,156	33,638	40,028	39,607	48,084
Telecommunications	10,121	11,093	11,810	12,416	13,328	15,223	17,994
Other public utilities	23,950	24,766	21,346	21,222	26,700	24,384	30,089
Railroads	3,340	3,509	4,398	4,922	5,736	4,918	4,226
Electric light and power	14,918	14,049	11,211	11,325	12,381	14,057	21,111
Gas	4,694	6,279	4,722	4,006	7,318	3,920	3,750
Petroleum pipelines	998	929	1,015	969	1,265	1,489	1,003
All other private	2,890	2,893	2,431	2,292	2,606	2,901	2,899
Public Construction	**120,193**	**129,933**	**139,263**	**154,882**	**159,523**	**172,673**	**174,860**
Buildings	49,446	57,754	63,471	71,867	73,277	77,690	82,275
Housing and redevelopment	3,835	4,698	5,048	5,230	5,124	5,618	5,228
Industrial	1,465	1,508	1,389	999	1,010	925	1,159
Educational	20,361	25,783	28,590	34,385	36,234	39,725	43,560
Hospital	3,951	4,236	4,617	5,152	3,906	3,968	4,007
Other	19,834	21,528	23,826	26,100	27,004	27,454	28,321
Highways and streets	37,419	37,616	39,464	44,105	48,515	53,532	52,088
Military facilities	2,318	3,011	2,591	2,556	2,529	2,111	2,337
Conservation and development	6,363	6,308	6,008	5,739	5,447	6,003	6,014
Sewer systems	8,700	8,420	9,798	10,392	10,168	11,181	10,287
Water supply facilities	4,647	4,709	5,618	6,419	6,830	7,602	6,928
Miscellaneous public	11,301	12,116	12,313	13,803	12,755	14,555	14,930

Rounding out the private construction component are farm non-residential, public utilities, and "all other private." These are generally of a non-residential nature, but are not part of non-residential buildings. Farm non-residential construction includes structures such as barns, storage houses, and fences. Land improvements such as leveling, terracing, ponds, and roads are also a part of this subcomponent. Privately owned public utilities construction is categorized by industry rather than function of the building or structure. This subcomponent includes expenditures made by utilities for telecommunications, railroads, petroleum pipelines, electric light and power, and natural gas. "All other private" includes privately owned streets and bridges, sewer and water facilities, airfields, and similar construction.

For public construction, there are two major components--building and non-building. Both the two major components and the various subcomponents are shown as headings in the first column of Tables 3-1 and 3-2. The building component contains subcomponents similar to those for private construction, with educational buildings being the largest subcomponent. Expenditures for the non-building component overwhelmingly consist of outlays for highways and streets, with sewer systems being a distant second subcomponent.

To get the sector totals, each subcomponent was assigned to a sector and summed. The sector assignments are identical to those used in Chapman and Rennison.[15] The sector totals and the overall total are recorded in Tables 3-3 and 3-4. Reference to the tables reveals that sector totals vary considerably, with residential being the largest and industrial the smallest.

Table 3-3. Value of Construction Put in Place: Sector Totals and Sum Total in Millions of Constant 1997 Dollars[16]

Sector	Value of Construction Put in Place ($ Millions)						
	1994	1995	1996	1997	1998	1999	2000
Residential	266,876	266,089	295,555	294,244	311,248	331,705	341,738
Commercial/ Institutional	152,521	165,828	184,237	205,703	215,774	221,308	233,329
Industrial	33,440	37,511	38,844	37,738	40,393	33,521	29,925
Public Works	118,434	117,111	115,034	118,944	125,459	128,671	129,280
Total - All Sectors	571,271	586,539	633,670	656,629	692,874	715,205	734,272

[15] Chapman, Robert E., and Roderick Rennison. 1998. *An Approach for Measuring Reductions in Operations, Maintenance, and Energy Costs: Baseline Measures of Construction Industry Practices for the National Construction Goals.* NISTIR 6185. Gaithersburg, MD: National Institute of Standards and Technology.

[16] Note that due to rounding the values entered in the "Total – All Sectors" row in Table 3-3, differ slightly from the values entered in the "Total Construction" row in Table 3-1.

Table 3-4. Value of Construction Put in Place: Sector Totals and Sum Total in Millions of Current Dollars[17]

Sector	Value of Construction Put in Place ($ Millions)						
	1994	1995	1996	1997	1998	1999	2000
Residential	242,709	252,049	286,163	294,244	319,731	354,444	379,502
Commercial/ Institutional	138,710	157,078	178,383	205,703	221,654	236,482	259,113
Industrial	30,412	35,532	37,609	37,738	41,494	35,819	33,232
Public Works	107,709	110,932	111,379	118,944	128,878	137,492	143,567
Total - All Sectors	519,540	555,591	613,534	656,629	711,757	764,237	815,414

Table 3-3 reveals that the commercial/institutional sector is the only sector to have grown consistently in real terms over the entire seven-year period. In real terms, expenditures in the commercial/institutional sector grew from $152.5 billion in 1994 to $233.3 billion in 2000, an increase of almost 55 %. Real expenditures for two of the four sectors, industrial and public works, were essentially constant over the same seven-year period. Real expenditures for the residential sector exhibited a cyclical pattern.

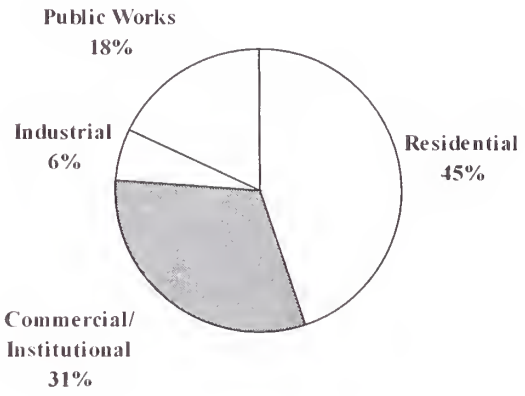
The data contained in Tables 3-3 and 3-4 provide the basis for calculating each sector's relative share of total construction expenditures. Each sector's relative share of total construction expenditures is shown graphically in pie chart form in Figure 3-1. It was constructed using 1997 data from Table 3-4 (i.e., current dollar expenditures). Figure 3-1 reveals that in 1997 the commercial/institutional sector accounted for 31 percent of total construction expenditures (i.e., 31 % of $656.6 billion). The commercial/institutional sector's relative share of total construction expenditures is exceeded only by the residential sector, which constitutes 45 % of the total. In addition, the commercial/institutional sector's relative share exceeds the combined total for the industrial and public works sectors.

3.2 Overview of the Commercial/Institutional Sector

The commercial/institutional sector, defined in economic terms, consists of establishments that provide services. Defined in this way, the commercial/institutional sector is extremely varied. It includes office buildings, service businesses (e.g., retail and wholesale stores, hotels and motels, restaurants, and hospitals), as well as a wide range of facilities that would not be considered "commercial" in a traditional sense (e.g., public schools, correctional institutions, and religious and fraternal organizations).

[17] Note that due to rounding the values entered in the "Total-All Sectors" row in Table 3-4 differ slightly from the values entered in the "Total Construction" row of Table 3-2.

Figure 3-1. 1997 Breakdown of $657 Billion Construction Market



Expenditures by establishments in the commercial/institutional sector for the built environment include construction expenditures (e.g., new construction and additions and alterations) as well as expenditures for facility operations, for maintenance and repair activities, and for energy. Consequently, it is instructive to first define what is included in each type of expenditure and then examine the characteristics of commercial/ institutional buildings that affect these expenditures.

Construction expenditures include both new construction activities and additions and alterations.

New construction activities include the complete original building of structures and essential service facilities and the initial installation of integral equipment (e.g., elevators and plumbing, heating, and air-conditioning supplies and equipment).

Additions and alterations include construction work that adds to the value or useful life of an existing building or structure, or which adapts a building or structure to a new or different use. Included are major replacements of building systems (e.g., installation of a new roof or heating system).

Facility operations include all non-process or end-product related activities required to operate a building or structure (e.g., water consumption, trash removal/environmental costs, cleaning services/janitorial, and security services/life safety costs), with the exception of maintenance and repair activities and energy. In some cases, fixed operations components may also be included (e.g., real estate and other taxes, insurance, and leasing expenses).

Maintenance and repair activities include incidental construction work that keeps a building or structure in ordinary working condition.

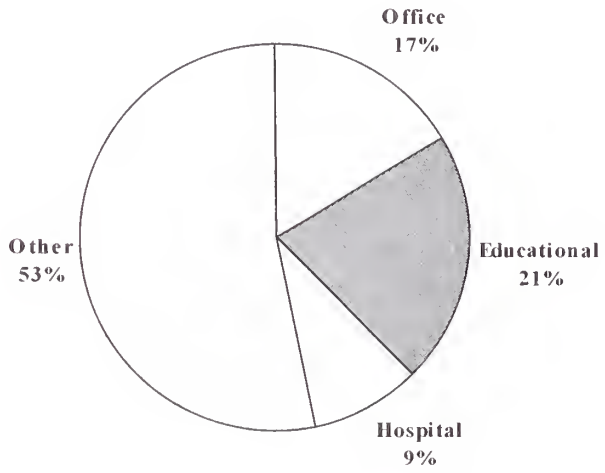
Energy is defined as including all non-process or end-product related energy consumption required to operate a building or structure. Energy consumption can be categorized by energy source (e.g., electricity, gas, and oil) and by end-use (e.g., space heating, cooling, and lighting).

Construction expenditures in 1997 for the commercial/institutional sector were $205.7 billion in current dollars (see Table 3-4). Total expenditures include expenditures from subcomponents listed under both the "private construction" and "public construction" headings in Tables 3-1 and 3-2. The subcomponents included under the private construction heading are: office, hotels and motels, other commercial, religious, educational, hospital and institutional, miscellaneous, and farm non-residential. The subcomponents included under the public sector heading are: educational, hospital, and other. Because the commercial/institutional sector is so varied, it is useful to group these subcomponents into a small number of key components. For convenience, these subcomponents are grouped into four key components, three of which are fairly homogeneous. The four key components are: educational, office, hospital, and other. The relative share of the overall commercial/institutional sector's construction expenditures for each of the four key components is shown graphically in pie chart form in Figure 3-2. It was constructed using 1997 data from Table 3-2 (i.e., current dollar expenditures). Reference to Figure 3-2 reveals that in 1997 the educational facilities component accounted for 21 percent of the commercial/institutional sector's construction expenditures.

A report[18] by Chapman and Rennison included information on operations, maintenance, and energy costs for the commercial/institutional sector. Wherever possible, Chapman and Rennison normalized data on a per unit area basis. If the data were sufficiently detailed, as was the case with energy data, they were classified into "bins" within which certain characteristics were homogeneous (e.g., building type, size, and age) and then normalized on a per unit area basis. Although there are a number of data sets which allow such in-depth analyses, the data associated with the Department of Energy's (DOE's) Commercial Building Energy Consumption Survey (CBECS) is the source of preference for summarizing the characteristics of the commercial/institutional sector's stock of buildings.

[18] Chapman and Rennison, *An Approach for Measuring Reductions in Operations, Maintenance, and Energy Costs*.

Figure 3-2. 1997 Breakdown of $206 Billion Commercial/Institutional Sector



The CBECS collects information on physical characteristics of commercial buildings, building use and occupancy patterns, equipment use, conservation features and practices, and types and uses of energy in buildings. The survey also collects information on the amount of energy consumed and the costs for energy in commercial buildings. The survey is conducted in two stages, the Building Characteristics Survey and the Energy Suppliers Survey. The focus of this section and the next is on the Building Characteristics Survey. Readers interested in the CBECS and its associated micro-data files are referred to Section 4.1.

The most recent DOE Commercial Buildings Characteristics report[19] provides detailed information on the size, age, and other characteristics of commercial/institutional buildings. In 1995, there were 4.58 million commercial buildings and 5.46 billion square meters (58.78 billion square feet) of commercial floorspace in the United States. The mean size of all commercial buildings was 1,193 m^2 (12,840 ft^2).[20] The DOE report grouped buildings into eight size categories and into eight age categories. The vast majority of commercial buildings were found in the smallest size categories, with more than half in the smallest category and three quarters in the two smallest categories. Most commercial buildings, once constructed, are expected to last for decades or longer. New buildings are constructed each year and older buildings are demolished, but the commercial buildings stock at any point in time is dominated by older buildings. More

[19] US Department of Energy. 1997. *Commercial Buildings Characteristics 1995*. DOE/EIA-E024695. Washington, DC: Energy Information Administration.

[20] Values of floorspace expressed in square meters are denoted by m^2. Values of floorspace expressed in square feet are denoted by ft^2.

than 70 percent of all commercial buildings and total floorspace were constructed prior to 1980, and more than 50 % of buildings and floorspace were constructed prior to 1970.

The DOE report also examined whether any changes in major characteristics had occurred between 1989 and 1995. The report concluded that the profiles of major characteristics of commercial buildings showed no statistically significant changes from 1989 to 1992 to 1995, the years in which the last three surveys were conducted.[21] Significant changes between surveys would occur if characteristics in the newest buildings (i.e., those constructed since the previous survey) were quite different, or if changes were made to buildings in the existing stock. However, each three-year increment of new buildings and floorspace was generally small compared to all buildings and floorspace in a given category and the changes that did occur were not great enough to be statistically significant.

The profiles of major characteristics which showed no significant changes included the total number of buildings, the total amount of floorspace, the distribution of floorspace by principal building activity (e.g., office buildings), the distribution of buildings by size of building, and the distribution of floorspace by census region. Consequently, the total floorspace associated with each of the major components shown in Figure 3-2 has remained constant over the same period of time. If this trend continues, then total floorspace for each key component will continue to remain constant. It is important to note that during the period covered by the last survey the commercial/institutional sector experienced steady growth in construction expenditures relative to the rest of the construction industry. Even during this period of growth in construction expenditures, total floorspace in the commercial/institutional sector remained constant.

3.3 Characteristics of Educational Facilities

In 1995, there were 309,000 educational facilities in the United States. Collectively, these 309,000 educational facilities had 719 million m^2 (7,740 million ft^2) of floorspace. Educational facilities had a mean size of 2,453 m^2 (25,100 ft^2).[22] Although there are a number of very large educational facilities, the key category of educational facilities is actually dominated by smaller buildings. On the other hand, the mean size of all educational facilities is nearly twice the mean size of all commercial/institutional buildings (1,193 m^2 (12,840 ft^2)).

Figures 3-3 through 3-8 provide detailed snapshots of the nation's stock of educational facilities. In each figure, information is classified along one of two major dimensions, either by building size, measured in terms of total floorspace, or by building age, measured in terms of year of construction. Each set of figures (e.g., Figures 3-3, 3-4, and 3-5) uses the same bar chart format to facilitate comparisons of characteristics.

Figures 3-3, 3-4, and 3-5 record the distribution of the number of educational facilities and total educational floorspace by building size. All three figures use the same eight

[21] *Commercial Buildings Characteristics 1995*, p. vii. and p.10.
[22] *Ibid.*, p. 5.

size categories specified in the DOE report. The DOE size categories are specified in customary units; they range from 1,001 ft^2 to 5,000 ft^2 (93.0 m^2 to 464.5 m^2) for the smallest size category to over 500,000 ft^2 (over 46,451.5 m^2) for the largest size category. The eight size categories, as defined in this section, are used throughout this report. To facilitate reference to the DOE report, customary units are shown on the left-hand axis and SI units on the right-hand axis of each figure.

Figure 3-3 records the distribution of the number of educational facilities by building size. Figure 3-3 shows clearly why smaller buildings dominate the key category of educational facilities. Nearly one third of the stock of educational facilities (100,000 of 309,000) is contained in the smallest size category, and more than one half (160,000 of 309,000) in the two smallest size categories. By contrast, only 12,000 buildings are contained in the three largest size categories, and less than 1,000 in the largest category.

Figure 3-4 shows a very different snapshot of the stock of educational facilities than was seen in Figure 3-3. Figure 3-4 records the distribution of total floorspace by building size. When the total floorspace associated with each size category is tabulated, the floorspace in the two smallest size categories and the largest size category are much less than the intermediate size categories.

Figure 3-5 introduces an additional characteristic, the number of floors in the building. This characteristic serves to sharpen the distinctions between the buildings in each size category. Figure 3-5 uses the same classification scheme as employed in the DOE report. DOE grouped educational facilities into one of five categories, based on the number of floors. These categories are one floor, two floors, three floors, four to nine floors, and ten or more floors. Each floor category is coded by shading; a legend is provided on the figure to match the floor category to a specific bar in each of the eight size categories. Figure 3-5 shows clearly how the distribution of total floorspace shifts as building size increases. For example, buildings with one and two floors dominate total floorspace in the three smaller size categories. As building size increases, the total floorspace in buildings with four or more floors rises quickly and then remains fairly steady.

Figures 3-6, 3-7, and 3-8 record the distribution of the number of educational facilities and total educational floorspace by year of construction. In all three figures, the years of construction are grouped into seven multi-year periods (i.e., categories). It is important to note that these seven year of construction categories differ from the eight year of construction categories specified in the DOE report. This is because the last two DOE year of construction categories have been combined. The last two DOE year of construction categories were 1990 to 1992 and 1993 to 1995. These categories were combined to form the 1990 to 1995 year of construction category. The year of construction categories used are 1919 or before, 1920 to 1945, 1946 to 1959, 1960 to 1969, 1970 to 1979, 1980 to 1989, and 1990 to 1995. The seven year of construction categories, as defined in this section, are used throughout this report.

Figure 3-3. Total Number of Educational Facilities by Size Category: 1995

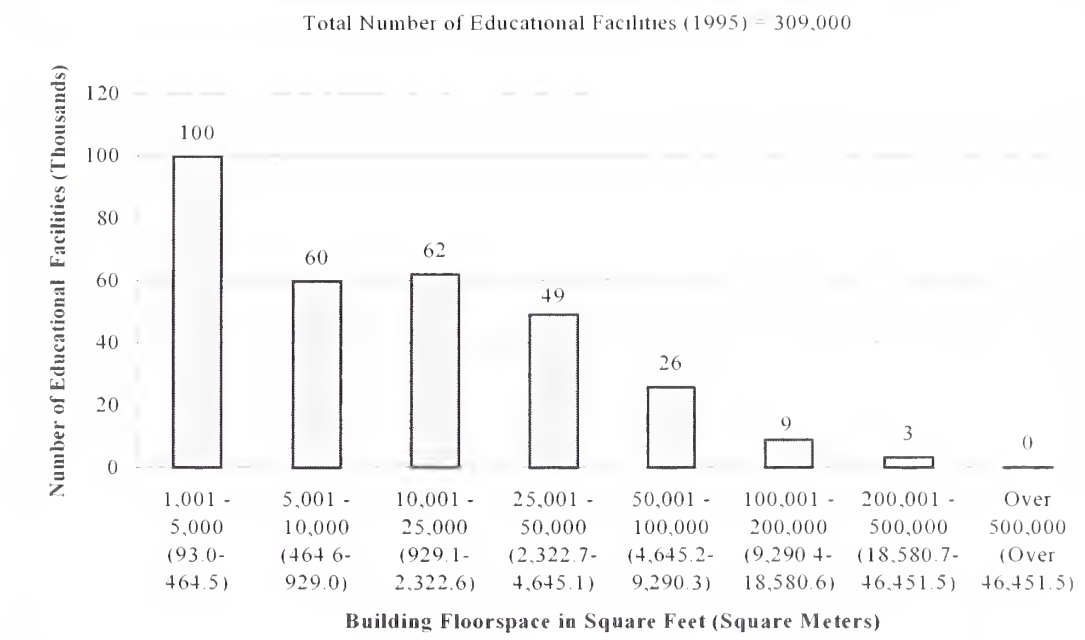


Figure 3-4. Total Educational Floorspace by Building Size Category: 1995

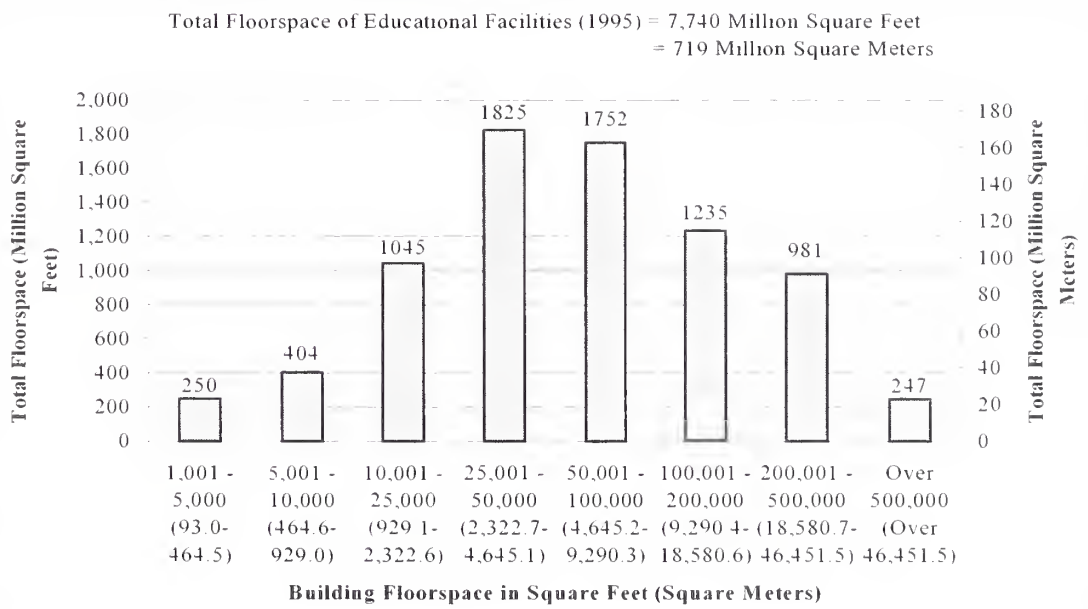


Figure 3-5. Total Educational Floorspace by Building Size Category and Number of Floors: 1995

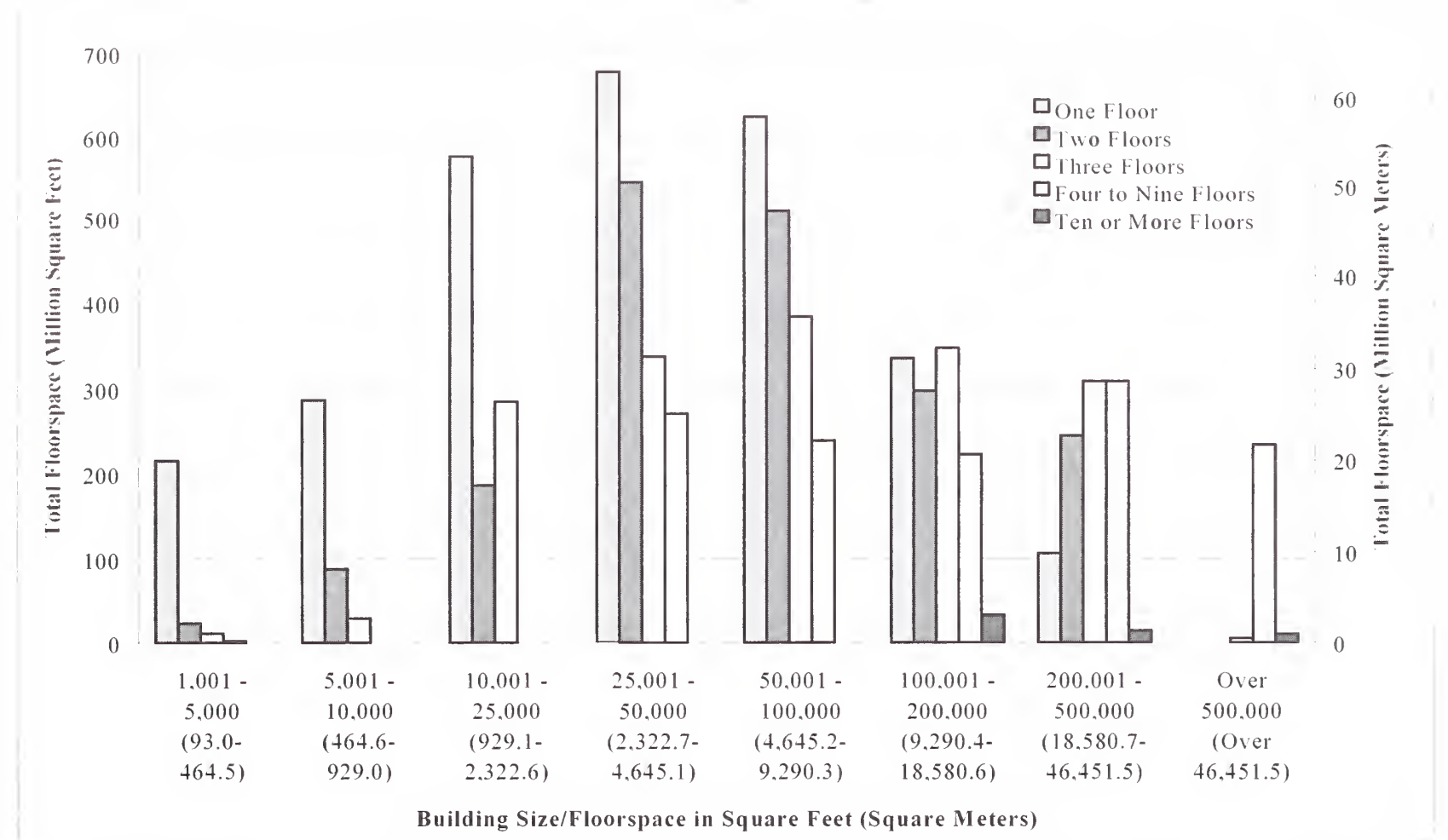


Figure 3-6 records the distribution of the number of educational facilities by year of construction. Figure 3-6 shows that five sixths of the stock of educational facilities (249,000 of 309,000) has been constructed since World War II.

Figure 3-7 records the distribution of floorspace by year of construction. Note that approximately one half of all educational floorspace was constructed between 1946 and 1969. In addition, educational floorspace put in place has been declining since 1970.

Figure 3-8 introduces information on the number of floors. Begin by comparing Figure 3-8 with Figure 3-5. Recall that Figure 3-5 showed a definite shift in the distribution of total floorspace among the floor categories as building size increased. When year of construction is the characteristic under investigation, a different pattern emerges. Basically, since 1946, the distribution of floorspace among the floor categories within a given year of construction category is skewed towards low-rise buildings. For each year of construction category since 1946, total floorspace for one and two floor buildings tends to exceed the floorspace for educational facilities with three or more floors. Although this outcome may seem puzzling at first, it is easily rationalized. In any extended period, say 1960 to 1969, the distribution of building sizes tends to take on the characteristics (e.g., shape) of the distribution of building sizes for the overall population. Thus the characteristics of the building size distribution for the 1960 to 1969 year of construction category would be similar to Figure 3-5, the distribution for the overall population. Consequently, summing across building size for each floor category would produce a declining staircase-type distribution with a relatively higher value of total floorspace for low-rise buildings.

Figure 3-6. Total Number of Educational Facilities by Year of Construction: 1995

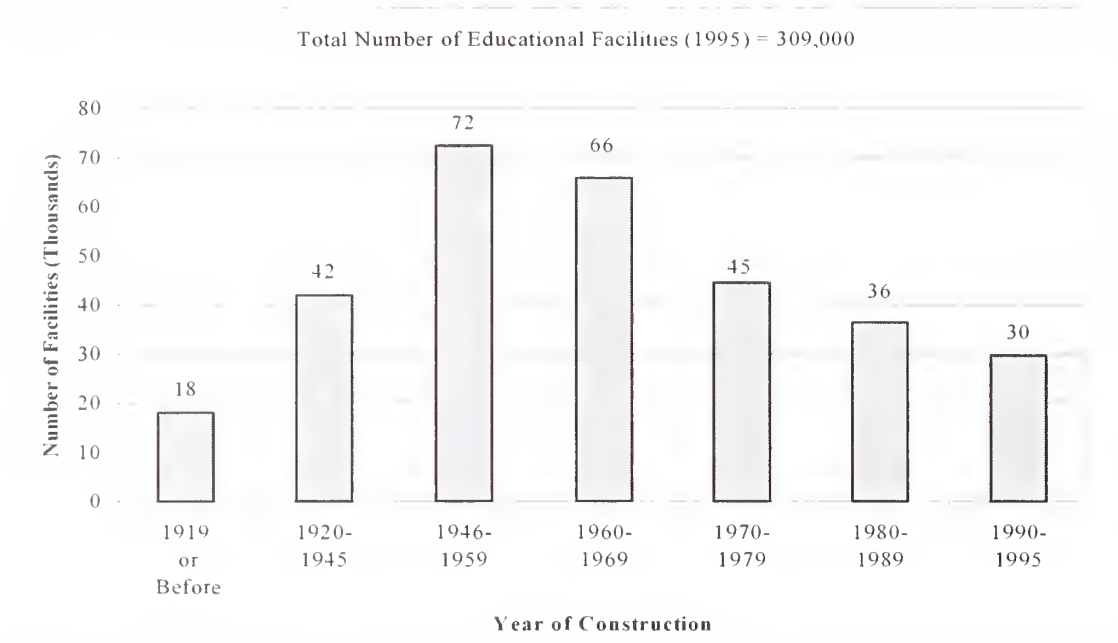


Figure 3-7. Total Educational Floorspace by Year of Construction: 1995

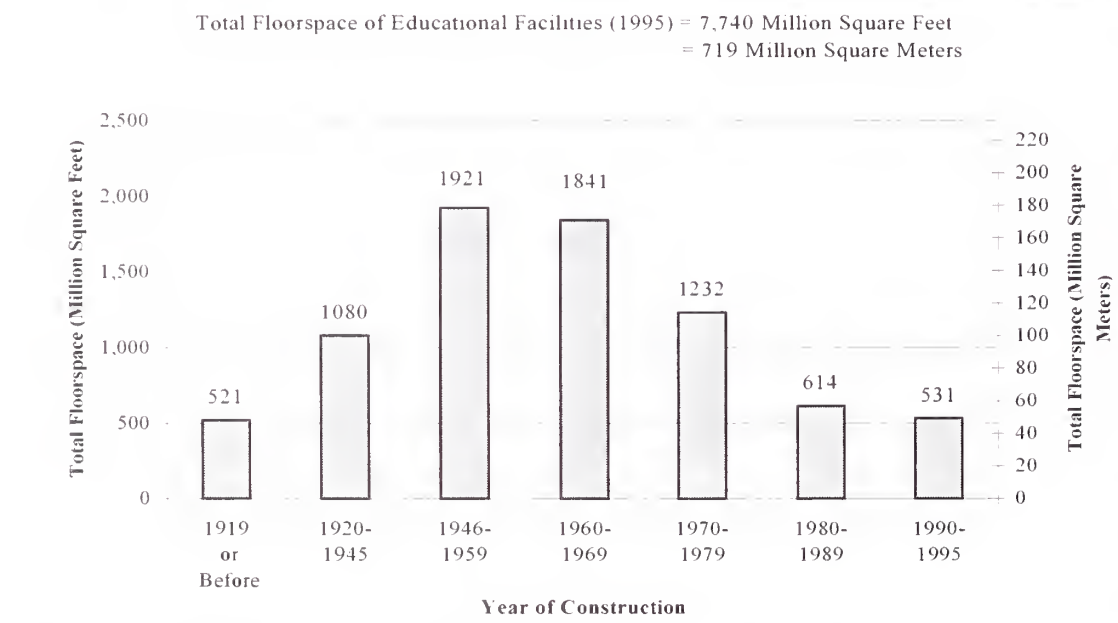


Figure 3-8. Total Educational Floorspace by Year of Construction and Number of Floors: 1995

4. OM&E Measures for Educational Facilities

This chapter traces the development of the OM&E baseline measures for educational facilities. Data sources are described and matched to the key types of educational facilities (i.e., K-12 and colleges and universities). The OM&E baseline measures are then derived from the source data. Information on energy conservation features is also included. The chapter concludes with a summary of the various OM&E baseline measures for educational facilities.

4.1 Data Considerations: Sources, Availability, and Constraints

Preliminary data searches for the commercial/institutional sector indicated that there were a variety of organizations that are carrying out systematic surveys of selected types of educational facilities, but that there are few surveys which cover all types of educational facilities. The most detailed survey of educational facilities which has been located by the author is carried out by the Energy Information Administration (EIA), a part of the US Department of Energy (DOE). Information from EIA, and other selected organizations, was examined in detail to determine how it might best be used to develop baseline measures for educational facilities. The principal data sources that are used in this document are described below.

Data from the Energy Information Administration

The DOE Commercial Buildings Energy Consumption Survey (CBECS) is used to establish the sources for two key data items: (1) the national average energy cost per m^2 (per ft^2); and (2) the rates of utilization of energy conserving features and practices. CBECS is a national sample survey that collects energy-related building characteristics and consumption and expenditure data for US commercial buildings. CBECS was first conducted in 1979 and then triennially since 1983.

In the 1995 CBECS, there were 6,590 sampled buildings of which 5,766 were successfully interviewed. Energy-related characteristics of the buildings are obtained in an on-site personal interview with the building managers, owners, or tenants during the Commercial Buildings Characteristics Survey. Energy consumption and expenditures information are obtained from the energy suppliers to the responding buildings during the Energy Suppliers Survey. The CBECS defines commercial buildings as enclosed roofed and walled structures used predominantly for commercial purposes with floorspace greater than 1,000 ft^2. This definition includes buildings such as schools, health care buildings, and religious institutions, as well as office buildings and retail stores.

The survey includes characteristics of each building sampled. One of these characteristics, principal building activity, is used to separate educational facilities from other types of commercial buildings. Readers interested in a detailed description of the

1995 CBECS are referred to the recent report by the Energy Information Administration.[23]

The information presented in this chapter is derived from data contained in the CBECS Public Use Files. The Public Use Files are microdata files that contain 5,766 records, representing commercial buildings from the 50 States and the District of Columbia. Each record corresponds to a single sampled building and contains information for that building about the building size, year constructed, types of energy used, energy-using equipment, energy consumption and expenditures, conservation features and energy management practices, and energy used for nine end uses. The nine end uses are space heating, cooling, ventilation, lighting, water heating, cooking, refrigeration, office equipment, and other.

The CBECS sample was designed so that survey responses could be used to estimate characteristics of the entire commercial buildings stock nationwide. In order to arrive at national estimates from the CBECS sample, DOE calculated base-sampling weights for each building. Therefore, a building with a base weight of 1,000 represents itself and 999 similar, but unsampled buildings in the total building stock. The base weight is further adjusted to account for nonresponse bias. In order to obtain a weighted estimate, each sample building's value must be multiplied by the building's weight.

Data from APPA: The Association of Higher Education Facilities Officers

APPA is an organization with more than 4,500 members representing learning institutions across the US and Canada, with universities and colleges representing the largest segment of the membership. APPA promotes the effective operation and maintenance of educational facilities through education and technical support of facility managers and others in the profession. The *APPA 1993-94 Comparative Costs and Staffing Report for College and University Facilities* (the second biennial report), [24] provides detailed information on facilities management costs and staffing information. It is based on 516 surveys carried out for the 1993-94 fiscal year. Data are presented which describe operations, maintenance, and energy costs for facilities, sorted by facility funding source, type, geographic location, and size of student population. Data from APPA are available through its Internet site (URL: http://www.appa.org) or through paper publications.

American School & University (AS&U) Magazine

AS&U Magazine serves chief administrators, facility managers, business officials, purchasing directors, and architects. The focus of the magazine is on facilities/business

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[23] US Department of Energy. 1998. *A Look at Commercial Buildings in 1995: Characteristics, Energy Consumption, and Energy Expenditures*. DOE/EIA-0625(95). Washington, DC: Energy Information Administration.

[24] The Association of Higher Education Facilities Officers. 1995. *1993-94 Comparative Costs and Staffing Report for Colleges and University Facilities.* Alexandria, VA: The Association of Higher Education Facilities Officers.

administration, including public and private schools and colleges and universities. AS&U also conducts and publishes an annual survey of maintenance and operations costs. Data from the *1996 AS&U Maintenance & Operations Case Study*[25] were used to produce "summary" measures of OM&E costs for K-12 facilities and for college and university facilities.

Data from Whitestone Research

The *Whitestone Building Maintenance and Repair Cost Reference 1996* is the second of a series of annual reports produced by Whitestone Research[26] which presents estimates of 50 year maintenance cost profiles for 24 different building models. Example building types are elementary schools, fast food restaurants, motels, auto service garages, offices, supermarkets, and movie theaters. These cover a good portion of the commercial/ institutional sector. The profile for each model includes a building description, a list of major building components, and forecasts of maintenance and repair costs at various levels of aggregation over the service life of the building. These can be adjusted for selected metropolitan areas, and modified to include different building components. The Whitestone Reports are available in paper form from Whitestone Research.

Data from Other Sources

- National Clearinghouse for Educational Facilities (NCEF). The NCEF is an information resource for people who plan, design, build, operate, and maintain K-12 schools. NCEF is funded by the US Department of Education and is an affiliated Clearinghouse of the National Library of Education's Educational Resource Information Center (ERIC). The National Institute of Building Sciences (NIBS) manages the NCEF.

- The Council of Educational Facility Planners, International (CEFPI). CEFPI serves individuals and firms who are responsible for planning, designing, creating, maintaining, and equipping educational facilities. CEFPI sponsors an exchange of information, professional experiences, best practices research results, and other investigative techniques concerning educational facility planning.

- *School Planning & Management Magazine* is written and edited to meet the business and information needs of the district-level buying team, including school board presidents, superintendents, business officials, facility planners, technology directors, and other school administrators working in public school systems serving K-12. The focus of the magazine is on solutions to management and operational problems in such areas as construction, facilities, technology, and purchasing.

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[25] American School & University. 1996. *1996 AS&U Maintenance & Operations Cost Study*. Overland Park, KS: American School & University.

[26] Lufkin, Peter S., and Anthony J.Pepitone. 1996. *The Whitestone Building Maintenance and Repair Cost Reference 1996*. Seattle, WA: Whitestone Research.

4.2 Baseline Measures for Educational Facilities

The OM&E baseline measures presented in this section are drawn from several key documents. To promote a better understanding of the terms employed in this section, a comprehensive list of OM&E cost components are identified and defined. These components include the following:

- **administration** - includes all administrative costs for the facility including payroll costs, equipment, supplies, communications, computer rental, accounting costs, and training costs
- **work control** - includes all costs necessary for the proper planning, scheduling, and dispatching of maintenance work, including payroll, database maintenance, supervision, and cost estimation
- **engineering/architecture** - includes all design and engineering costs
- **project management** - includes all costs associated with actual estimating, contracting, inspecting, and final approval of new or renovated construction
- **building maintenance** - includes in-house and contracted services for routine repairs, minor corrective maintenance, preventive maintenance and service calls for HVAC, plumbing, electrical, painting, glazing, and elevators
- **custodial maintenance** - includes interior and exterior functions such as window and building cleaning, snow removal, and operating costs such as towels
- **grounds maintenance** - includes landscaping and grounds maintenance costs for parking areas, irrigation systems, and fencing
- **utilities operations** - includes all costs for heating, cooling, lighting, and other utilities for physical plant operations, excluding cost of fuel and purchased utilities
- **solid waste disposal** - includes all costs associated with refuse removal
- **hazardous waste disposal** - includes all costs associated with hazardous waste removal
- **security** - includes all security expenses such as traffic, parking, and building security

4.2.1 Baseline Measures for K-12 Facilities

Data from the *1996 AS&U Maintenance & Operations Cost Study* and the *Whitestone Building Maintenance and Repair Cost Reference 1996* are used to develop baseline measures for OM&E costs for K-12 facilities. Both sets of information are needed because the AS&U data do not include estimates for major repairs and replacements. Although the Whitestone data include estimates of both maintenance and repair costs, the Whitestone maintenance cost data are aggregated totals and hence provide less detail than the AS&U maintenance cost data. All data presented in this subsection are recorded in 1996 dollars.

Table 4-1 presents selected median operation, maintenance, and energy cost data for K-12 facilities. These data are grouped into four major categories. These categories are: (1) in-house labor; (2) outside labor contract; (3) energy and water/sewer; and (4) supplies. The last row of the table records the total median OM&E costs for K-12 facilities.

Reference to Table 4-1 reveals that more than half of the OM&E cost total is for in-house labor. The next largest cost category is for energy and water (i.e., fuel, electricity, and water/sewer). Supplies and outside labor contract services account for the remainder.

Table 4-1. Annual Operations, Maintenance, and Energy Costs for K-12 Facilities

Cost Category	K-12 Facilities	
	Dollars per Square Foot	Dollars per Square Meter
Payroll ($)		
Custodial	$1.22	$13.13
Maintenance	$0.48	$5.17
Grounds	$0.17	$1.83
Outside Labor Contract	$0.20	$2.15
Fuel	$0.25	$2.69
Electricity	$0.56	$6.03
Water/Sewer	$0.17	$1.83
Equipment & Maintenance Supplies	$0.23	$2.48
Grounds Equipment & Supplies	$0.05	$0.54
Total OM&E Costs	**$3.32**	**$35.74**

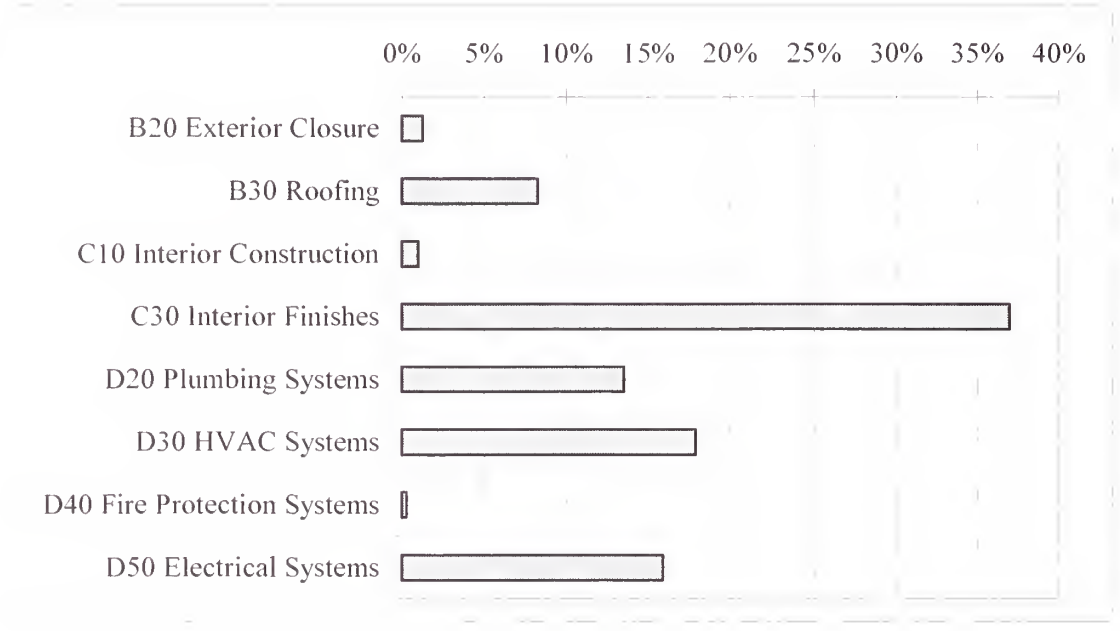
The distribution of major repair costs is recorded in Figure 4-1. This distribution is based on data published by Whitestone Research. The data are classified into major cost categories according to ASTM's *Standard Classification for Building Elements and Related Sitework—UNIFORMAT II.*[27] The repair cost data are based on a 47,000 ft^2 elementary school. The total (undiscounted) major repair cost per gross ft^2 over the 50 year period used by Whitestone Research for this facility is $69.00.

Figure 4-1 reveals that more than one third of major repair costs are associated with interior finishes. Only three other systems exceed ten percent of the total major repair cost per gross ft^2 over the 50-year period. These systems are: (1) HVAC; (2) Electrical; and (3) Plumbing.

Table 4-2 records the most costly major repair tasks. These tasks are ranked in descending order. Associated with each task is a task cost in dollars per ft^2 and a percent, expressed as a percent of the total maintenance and repair cost per gross ft^2 over the 50 year analysis period. Notice that the most costly major repair tasks are due to the replacement of fluorescent lighting fixtures $90.31/m^2$ ($8.39/ft^2$), the refinishing of plaster wall finishes $86.97/m^2$ ($8.08/ft^2$), the replacement of quarry tile floors $81.27/m^2$ ($7.55/ft^2$), and the refinishing of plaster ceilings $67.28/m^2$ ($6.25/ft^2$).

[27] American Society for Testing and Materials. 1998. *Standard Classification for Building Elements and Related Sitework—UNIFORMAT II.* E-1557. West Conshohocken, PA: American Society for Testing and Materials.

Figure 4-1. Distribution of Major Repair Costs by Building Element Over a 50-Year Period



4.2.2 Baseline Measures for College and University Facilities

Data from the *1996 AS&U Maintenance & Operations Cost Study* are used to produce a set of "summary" measures. These data are recorded in Table 4-3. Table 4-3 presents selected median OM&E cost data for college and university facilities. These data are grouped into four major categories. These categories are: (1) labor; (2) energy and water/sewer; (3) supplies; and (4) equipment. The last row of the table records the total OM&E costs for college and university facilities.

Reference to Table 4-3 reveals that more than half of the OM&E cost total is for labor (i.e., salaries plus fringe). The next largest cost category is for energy and water. Supplies and equipment maintenance/purchases account for the remainder.

Data from the Association of Higher Education Facilities Officers (APPA) are used to establish detailed OM&E baseline measures for college and university facilities. These data were collected in 1995 for the 1993-94 fiscal year. It should be noted that data presented here represent only the most general of the data available in the *APPA Comparative Costs and Staffing Report for Colleges and University Facilities.*

Table 4-2. Most Costly Major Repair Tasks Over a 50 Year Period

Major Repair Task	Task Cost [1]		Percent [2]
	Dollars per Square Foot	Dollars per Square Meter	
Replace Fluorescent Lighting Fixture, 160 W	$8.39	$90.31	6.0 %
Refinish Plaster Wall Finish	$8.08	$86.97	5.7 %
Replace Quarry Tile Floor	$7.55	$81.27	5.4 %
Refinish Plaster Ceiling	$6.25	$67.27	4.4 %
Replace Pipe & Fittings, 2" Copper, Cold Water	$4.09	$44.02	2.9 %
Place New Membrane Over Existing Built-up Roof	$3.45	$37.14	2.5 %
Replace Vinyl Tile Flooring	$3.40	$36.60	2.4 %
Replace Chiller, Reciprocal Water-Cooled Hermetic, 165 Tons	$3.40	$36.60	2.4 %
Replace Air Handler, Multizone, 50,000 Cfm	$2.64	$28.42	1.9 %
Membrane Removal & Replacement, Built-up Roof	$2.54	$27.34	1.8 %
Replace Pipe & Fitting 3/4" Copper, Cold Water	$2.40	$25.83	1.7 %
Repair Chiller, Reciprocal Water-Cooled Hermetic, 165 Tons	$1.96	$21.10	1.4 %
Replace Cooling Tower, 200 Ton	$1.50	$16.15	1.1 %
Replace Air Handler, Multizone, 15,000 Cfm	$1.42	$15.28	1.0 %
Refinish Concrete Exterior Wall 1st Floor	$0.89	$9.58	0.6 %
Replace Carpet, Nylon 20 oz., Low Traffic	$0.81	$8.72	0.6 %
Replace Pipe Insulation, Cold Water	$0.77	$8.29	0.5 %
Replace Smoke Detector	$0.75	$8.07	0.5 %
Replace Transformer, Dry, less than 15,000 V	$0.72	$7.75	0.5 %
Replace Pipe & Fittings, 3/4" Copper, Hot Water	$0.67	$7.21	0.5 %
Replace Circulation Pump 5 Hp, Chiller & Condenser Water	$0.65	$7.00	0.5 %
Replace Gas Boiler, 2500 Mbh	$0.61	$6.57	0.4 %
Replace Solid Core (w/ Safety Glass) Painted Interior Door	$0.55	$5.92	0.4 %
Refinish Concrete Block (Painted) Wall	$0.41	$4.41	0.3 %
Replace Motor Starter, 21-50 Hp, <600 V	$0.36	$3.88	0.3 %
Replace Water Heater, Gas/Oil 130 Gph	$0.31	$3.34	0.2 %
Replace Receptacle and Plug	$0.29	$3.12	0.2 %
Repair Cooling Tower, 200 Ton	$0.28	$3.01	0.2 %
Replace Pipe Insulation, Hot Water	$0.26	$2.80	0.2 %
Replace Tankless Water Closet	$0.22	$2.37	0.2 %

[1] Task cost $742.72/m^2 ($69/ft^2) over 50 years (undiscounted).

[2] Percent of total maintenance and repair costs $1517.72/m^2 ($141/ft^2) over 50 years (undiscounted).

Table 4-3. Annual Operations, Maintenance, and Energy Costs for College and University Facilities

Cost Category	All Colleges and Universities	
	Dollars per Square Foot	Dollars per Square Meter
Salaries	$1.42	$15.28
Benefits	$0.40	$4.31
Energy	$1.07	$11.52
Water/Sewer	$0.11	$1.18
Supplies	$0.29	$3.12
Equipment Maintenance	$0.11	$1.18
Equipment Purchases	$0.11	$1.18
Total OM&E Costs	**$3.51**	**$37.78**

Table 4-4 Part A and Part B presents selected aggregated mean operations, maintenance, and energy cost data for college and university facilities grouped by funding source, region, and by number of Full-Time Equivalent (FTE) enrollment students at the facility.

Figures 4-2 through 4-5 show selected mean operations costs in dollars per gross m^2 (ft^2). Figure 4-2 compares selected operations costs for all college and university facilities combined. The figure shows that building maintenance, custodial maintenance (cleaning), and utility operations (which exclude the cost of fuels) are the largest cost components, in addition to fuel costs.

Figure 4-3 compares building and custodial maintenance costs for colleges and facilities by the size of the establishment (as measured by the number of FTE students). Reference to the figure indicates that there is no apparent downward trend in unit costs for larger facilities as might be expected. Figure 4-4, which is based upon data presented in Table 4-5 Part A and Part B, shows electricity costs for educational facilities by funding source. The figure indicates that private institutions have approximately 10 % lower electricity costs per unit area compared with publicly funded facilities. Reference to Table 4-5 also indicates that there are significant regional differences in total electricity costs in the US. The mean electricity cost for all facilities combined is $10.75/gross m^2 ($0.99/gross ft^2).

Figure 4-5, which is based upon data presented in Table 4-6 Part A and Part B, shows gas consumption by funding source for all educational facilities. Reference to the figure indicates that privately funded facilities have higher consumption costs than publicly funded sources. Comparison of Figure 4-4 and Figure 4-5 shows that private and publicly funded facilities have comparable energy costs per unit area when electricity and gas costs are combined.

Table 4-4. Selected Annual Operations Costs for College and University Facilities by Funding Source, Region, and Number of Students

Part A: Dollars per Square Foot

Carnegie Classification	Administrative Costs	Work Control	Engineering & Architecture	Project Management	Building Maintenance	Custodial Maintenance	Grounds Maintenance	Utilities Operations	Solid Waste Disposal	Hazardous Waste Disposal	Security
Funding Source											
Private Institutions	0.258	0.087	0.106	0.104	0.989	0.846	0.280	0.698	0.066	0.048	0.355
Public Institutions	0.264	0.076	0.114	0.114	0.851	0.942	0.273	0.554	0.046	0.032	0.353
All Institutions	0.262	0.079	0.112	0.112	0.895	0.912	0.275	0.594	0.052	0.037	0.354
Region											
Eastern	0.314	0.089	0.158	0.170	0.988	1.022	0.260	0.635	0.079	0.031	0.487
Southeastern	0.240	0.071	0.087	0.106	0.953	0.846	0.303	0.548	0.054	0.030	0.406
Midwest	0.238	0.079	0.092	0.058	0.825	1.003	0.244	0.678	0.037	0.029	0.291
Central	0.202	0.062	0.080	0.053	0.695	0.716	0.207	0.536	0.027	0.032	0.246
Rocky Mountain	0.208	0.082	0.090	0.101	0.810	0.807	0.264	0.597	0.032	0.021	0.209
Pacific Coast	0.367	0.084	0.138	0.130	1.117	1.013	0.440	0.509	0.060	0.075	0.351
Number of Students											
0-1,999	0.278	0.100	0.095	0.128	0.946	0.817	0.268	0.753	0.060	0.048	0.271
2,000-4,999	0.289	0.090	0.120	0.155	0.912	0.966	0.300	0.666	0.058	0.025	0.374
5,000-11,999	0.234	0.075	0.151	0.139	0.846	0.991	0.284	0.425	0.051	0.038	0.430
12,000-19,999	0.300	0.055	0.081	0.065	0.897	0.907	0.253	0.897	0.907	0.253	0.564
20,000+	0.162	0.063	0.081	0.055	0.831	0.915	0.218	0.606	0.041	0.031	0.343

Part B: Dollars per Square Meter

Carnegie Classification	Administrative Costs	Work Control	Engineering & Architecture	Project Management	Building Maintenance	Custodial Maintenance	Grounds Maintenance	Utilities Operations	Solid Waste Disposal	Hazardous Waste Disposal	Security
Funding Source											
Private Institutions	2.776	0.936	1.141	1.119	10.642	9.103	3.013	7.510	0.710	0.516	3.820
Public Institutions	2.841	0.818	1.227	1.227	9.157	10.136	2.937	5.961	0.495	0.344	3.798
All Institutions	2.819	0.850	1.205	1.205	9.630	9.813	2.959	6.391	0.560	0.398	3.809
Region											
Eastern	3.379	0.958	1.700	1.829	10.631	10.997	2.798	6.833	0.850	0.334	5.240
Southeastern	2.582	0.764	0.936	1.141	10.254	9.103	3.260	5.896	0.581	0.323	4.369
Midwest	2.561	0.850	0.990	0.624	8.877	10.792	2.625	7.295	0.398	0.312	3.131
Central	2.174	0.667	0.861	0.570	7.478	7.704	2.227	5.767	0.291	0.344	2.647
Rocky Mountain	2.238	0.882	0.968	1.087	8.716	8.683	2.841	6.424	0.344	0.226	2.249
Pacific Coast	3.949	0.904	1.485	1.399	12.019	10.900	4.734	5.477	0.646	0.807	3.777
Number of Students											
0-1,999	2.991	1.076	1.022	1.377	10.179	8.791	2.884	8.102	0.646	0.516	2.916
2,000-4,999	3.110	0.968	1.291	1.668	9.813	10.394	3.228	7.166	0.624	0.269	4.024
5,000-11,999	2.518	0.807	1.625	1.496	9.103	10.663	3.056	4.573	0.549	0.409	4.627
12,000-19,999	3.228	0.592	0.872	0.699	9.652	9.759	2.722	9.652	9.759	2.722	6.069
20,000+	1.743	0.678	0.872	0.592	8.942	9.845	2.346	6.521	0.441	0.334	3.691

Figure 4-2. Selected Annual Operations Costs for College and University Facilities

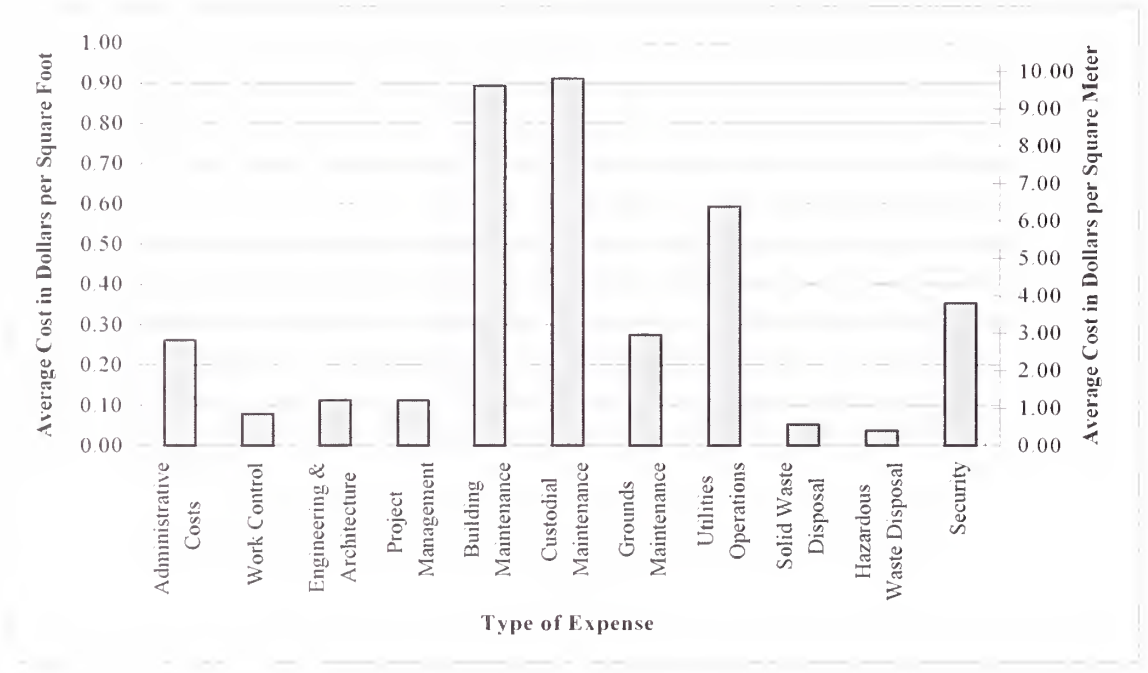


Figure 4-3. Annual Building and Custodial Maintenance Costs for Colleges and Universities by Number of Students

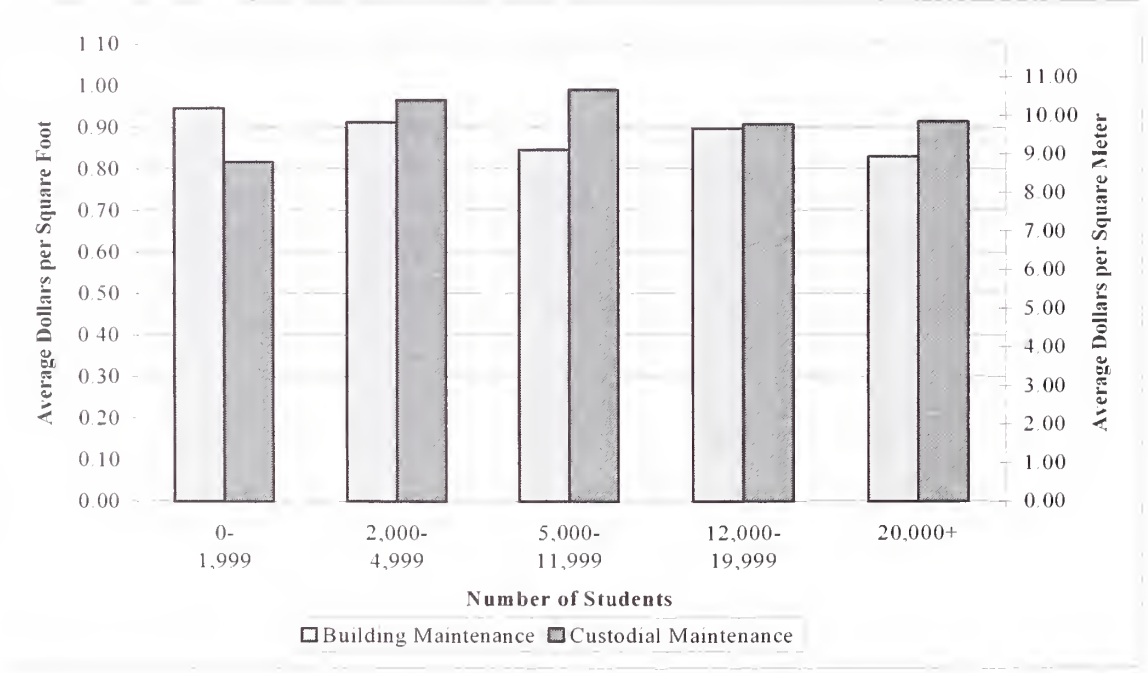


Figure 4-4. Annual Electricity Cost by Funding Source for Colleges and Universities

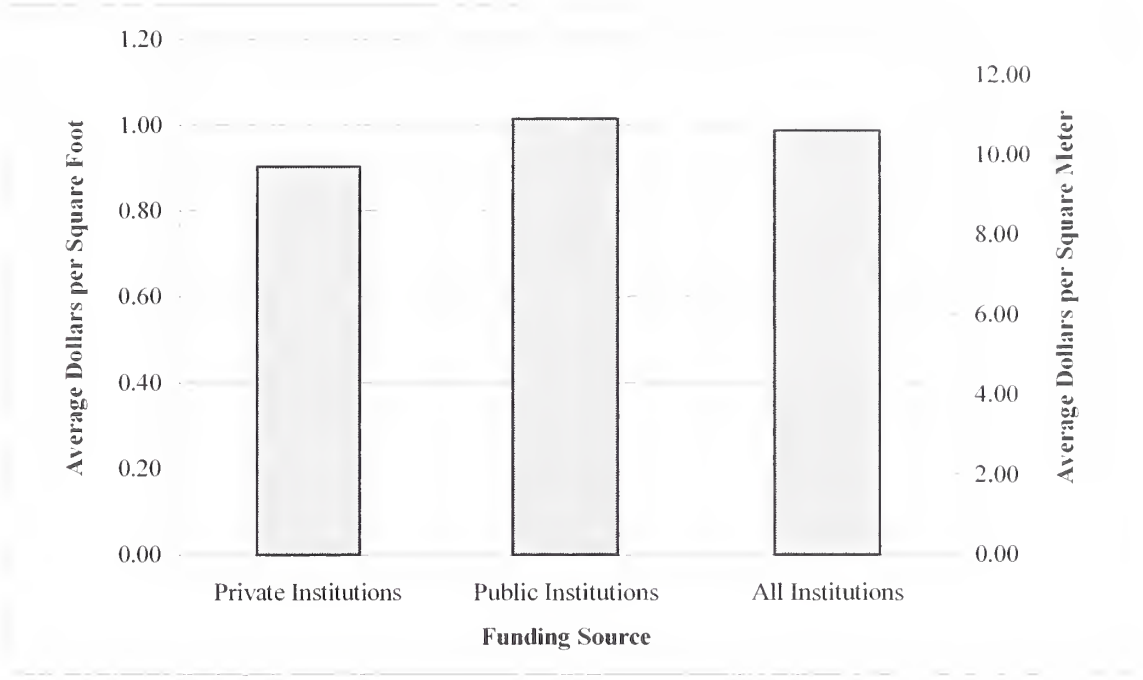


Figure 4-5. Annual Mean Gas Cost by Funding Source for Colleges and Universities

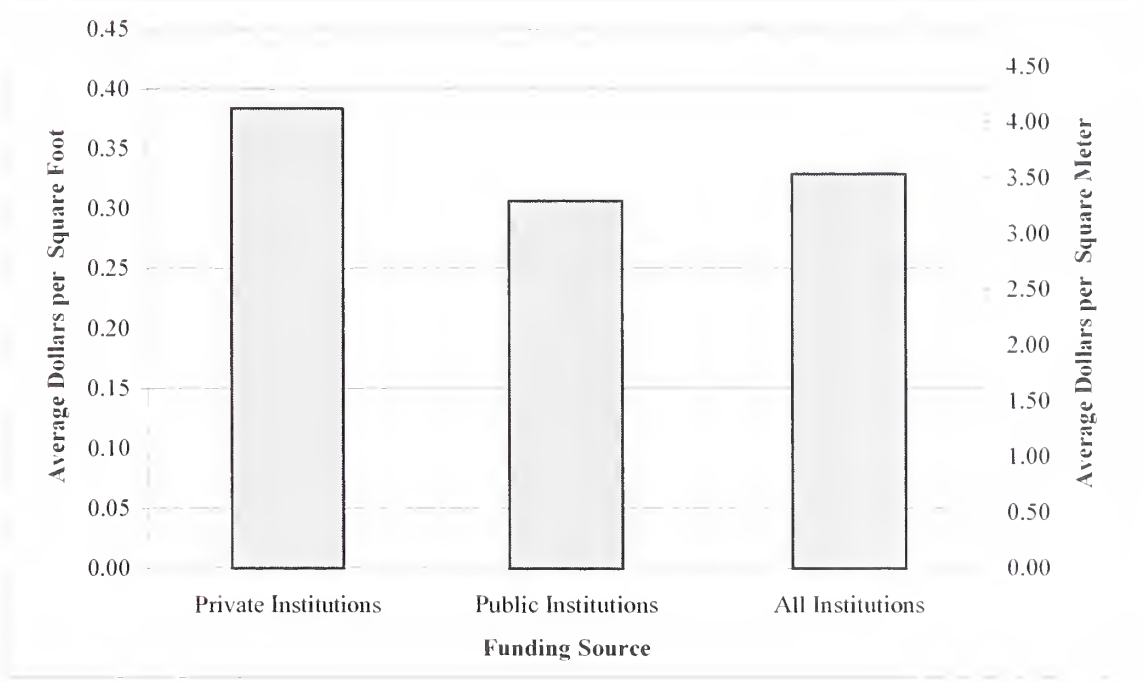


Table 4-5. Annual Mean Electricity Usage for College and University Facilities by Funding Source, Region, and Number of Students

Part A: English Units

Carnegie Classification	Cost per kwh	Kwh per Gross Building Square Foot	Cost per Gross Building Square Foot	Kwh per FTE Student	Cogeneration Cost per kwh
Funding Source					
Private Institutions	0.069	13.1	0.904	6,725	0.040
Public Institutions	0.059	17.2	1.015	4,186	0.042
All Institutions	0.062	15.9	0.986	4,983	0.041
Region					
Eastern	0.077	14.3	1.101	4,718	0.050
Southeastern	0.056	19.5	1.092	6,372	0.037
Midwest	0.059	16.6	0.979	5,292	0.037
Central	0.053	16.1	0.853	5,115	0.043
Rocky Mountain	0.053	13.0	0.689	2,839	0.040
Pacific Coast	0.067	14.0	0.938	3,842	0.040
Number of Students					
0-1,999	0.067	14.1	0.945	7,430	0.061
2,000-4,999	0.062	15.2	0.942	4,612	0.045
5,000-11,999	0.061	16.9	1.031	3,711	0.044
12,000-19,999	0.063	16.3	1.027	3,310	0.039
20,000+	0.053	19.5	1.034	4,547	0.032

Part B: SI Units

Carnegie Classification	Cost per MJ	MJ per Gross Building Square Meter	Cost per Gross Building Square Meter	MJ per FTE Student	Cogeneration Cost per MJ
Funding Source					
Private Institutions	0.019	507.6	9.730	24,210	0.011
Public Institutions	0.016	666.5	10.924	15,070	0.012
All Institutions	0.017	616.1	10.612	17,939	0.011
Region					
Eastern	0.021	554.1	11.853	16,985	0.014
Southeastern	0.016	755.6	11.755	22,939	0.010
Midwest	0.016	643.3	10.543	19,051	0.010
Central	0.015	623.9	9.186	18,414	0.012
Rocky Mountain	0.015	503.8	7.417	10,220	0.011
Pacific Coast	0.019	542.5	10.097	13,831	0.011
Number of Students					
0-1,999	0.019	546.4	10.169	26,748	0.017
2,000-4,999	0.017	589.0	10.145	16,603	0.013
5,000-11,999	0.017	654.9	11.097	13,360	0.012
12,000-19,999	0.018	631.6	11.054	11,916	0.011
20,000+	0.015	755.6	11.125	16,369	0.009

Table 4-6. Annual Mean Gas Consumption for College and University Facilities by Funding Source, Region, and Number of Students

Part A: English Units

Carnegie Classification	Cost per 100 Cubic Feet	Quantity per Gross Building Square Foot	Cost per Gross Building Square Foot	Quantity per FTE Student
Funding Source				
Private Institutions	0.48	0.80	0.38	357.20
Public Institutions	0.42	0.73	0.31	201.10
All Institutions	0.44	0.75	0.33	248.30
Region				
Eastern	0.53	0.72	0.38	223.50
Southeastern	0.51	0.62	0.31	178.00
Midwest	0.38	0.92	0.34	334.80
Central	0.35	0.73	0.26	295.80
Rocky Mountain	0.42	0.89	0.37	206.70
Pacific Coast	0.43	0.64	0.27	182.00
Number of Students				
0-1,999	0.47	0.86	0.40	430.10
2,000-4,999	0.46	0.61	0.28	219.20
5,000-11,999	0.44	0.72	0.32	146.20
12,000-19,999	0.42	0.67	0.28	159.50
20,000+	0.35	0.98	0.34	228.40

Part B: SI Units

Carnegie Classification	Cost per 100 Cubic Meters	Quantity per Gross Building Square Meter	Cost per Gross Building Square Meter	Quantity per FTE Student
Funding Source				
Private Institutions	16.95	.24	4.13	10.11
Public Institutions	14.83	.22	3.30	5.69
All Institutions	15.54	.23	3.55	7.03
Region				
Eastern	18.72	.22	4.11	6.33
Southeastern	18.01	.19	3.40	5.04
Midwest	13.42	.28	3.76	9.48
Central	12.36	.22	2.75	8.38
Rocky Mountain	14.83	.27	4.02	5.85
Pacific Coast	15.19	.20	2.96	5.15
Number of Students				
0-1,999	16.60	.26	4.35	12.18
2,000-4,999	16.24	.19	3.02	6.21
5,000-11,999	15.54	.22	3.41	4.14
12,000-19,999	14.83	.20	3.03	4.52
20,000+	12.36	.30	3.69	6.47

4.2.3 Energy Conservation in Educational Facilities

As noted earlier, the DOE Commercial Buildings Energy Consumption Survey (CBECS) is used to establish the sources for two key data items: (1) the national average energy cost per m^2 (per ft^2); and (2) the rates of utilization of energy conserving features and practices. CBECS is a national sample survey that collects energy-related building characteristics and consumption and expenditure data for US commercial buildings.

Figures 4-6 through 4-13 summarize the information on educational facilities extracted from the CBECS microdata files. With the exception of Figure 4-7, which is organized by year of construction, all of the figures record building size on the horizontal axis. The same eight size categories introduced in Chapter 3 are used in each figure. Tic marks on the horizontal axis are used to help separate the size categories. Two different measures are recorded on the vertical axis. For Figure 4-6 the vertical axis records the annual fuel expenditure per unit of floor area. For Figure 4-7 the vertical axis records the annual fuel expenditure by year of construction. For Figures 4-8 through 4-13 the vertical axis records the percent of total floorspace covered by the factors (i.e., end-use equipment and energy conservation features) under analysis. It is important to recognize that portions of a building's floorspace may be covered by more than one factor. Consequently, the sum total across all factors may exceed 100 % of total floorspace.

Figure 4-6 shows how annual energy expenditures per unit of floor area vary by building size. The figure also records the national average energy expenditure per m^2 (per ft^2). Reference to the figure shows that the national average energy expenditure is $\$9.90/m^2$ ($\$0.92/ft^2$). Examination of the figure shows considerable variability about the national average across the eight building size categories. With the exception of the two smallest size categories, the figure does not show any trend towards higher or lower energy expenditures per unit of floor area as building size increases.

Figure 4-7 shows how annual energy expenditures per unit of floor area vary by year of construction. The figure also records the national average energy expenditure per m^2 (per ft^2). Examination of the figure shows a slight upward trend in annual energy expenditures per unit of floor area, for facilities constructed prior to 1990.

Figures 4-8 through 4-13 are concerned with end-use equipment and energy conservation features. Energy is used within buildings by end-use equipment. End-use equipment refers to the specific type of equipment that is used to perform a given end use. Types of end-use equipment include heat pumps, furnaces, packaged air-conditioning units, central chillers, fluorescent light fixtures, and compact fluorescent bulbs. Figures 4-8 through 4-10 record information on end-use equipment.

Figure 4-6. Sum of Annual Major Fuel Expenditures of Educational Facilities by Building Size Category

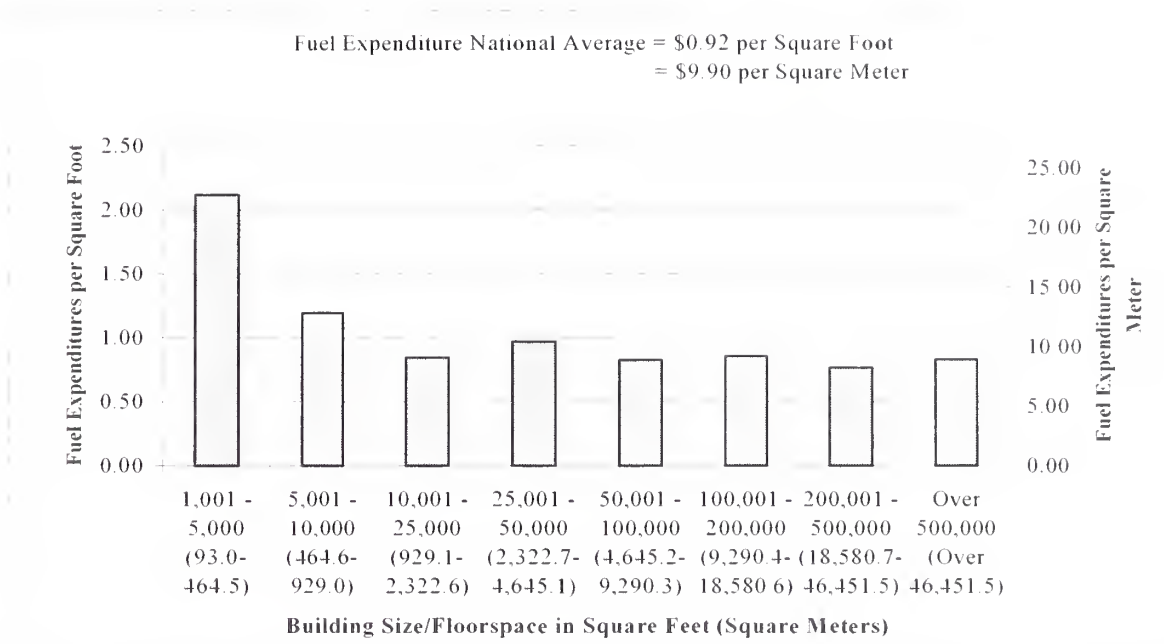
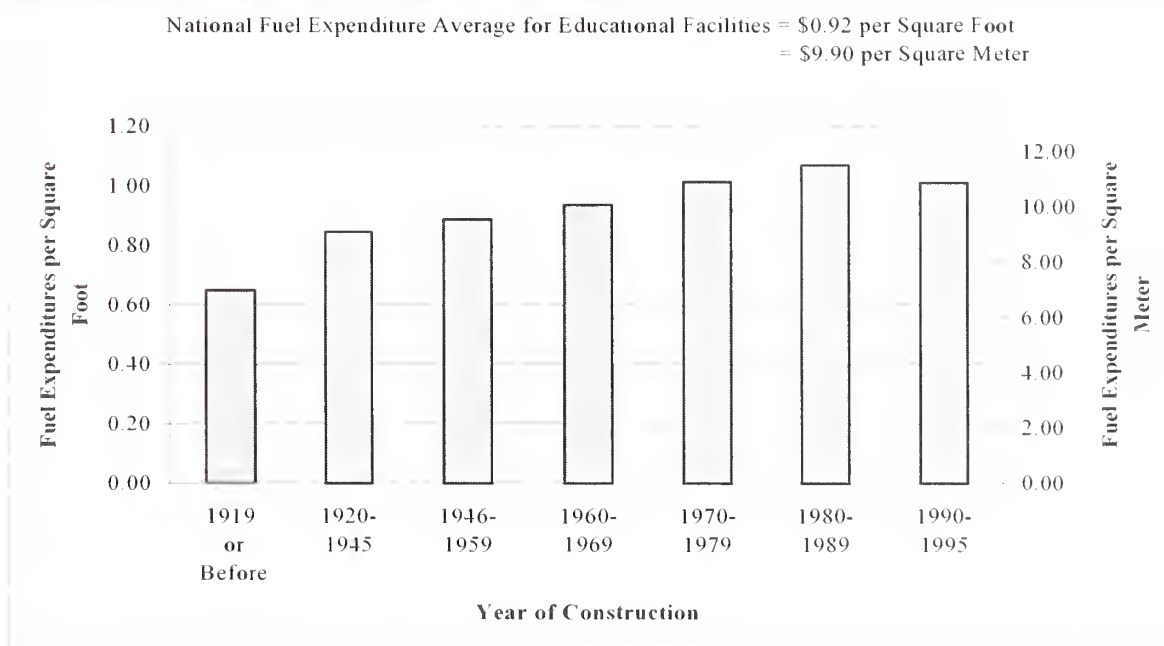


Figure 4-7. Sum of Annual Major Fuel Expenditures of Educational Facilities by Year of Construction



Educational facilities use a variety of features to conserve the use of energy by end-use equipment. Energy conservation features include those related to the building shell, HVAC systems, and lighting systems. Figures 4-11 through 4-13 record information on energy conservation features.

For Figures 4-8 through 4-13 the factors under analysis are listed in a box beneath the legend for the horizontal axis. The number of factors analyzed in each figure range from a high of seven (see Figure 4-8) to a low of four (see Figure 4-12). Each factor is cross-referenced to a bar in the figure. This is done by shading each bar, and for selected bars bolding their border. Each factor is indicated by a small shaded box and a factor name pairing. To identify a specific factor, start at the top and read from left to right across the shaded box/factor name pairings until the factor of interest is found. Note that each factor is recorded for each size category in Figures 4-8 through 4-13. Due to different building characteristics, some factors will have a zero value for some size categories. In such cases, a gap will appear between one or more bars. The positions of each bar, however, will be the same as indicated by the order of the shaded box/factor name pairings. As noted earlier, portions of a building's floorspace may be covered by more than one factor. Consequently, the sum across all factors may exceed 100 % of total floorspace.

Information on space heating equipment for educational facilities is presented in Figure 4-8. Three types of heating equipment were used extensively in educational facilities: packaged heating units, boilers, and district heat. Although all three types were used extensively, their use in educational facilities of different sizes varied considerably. For example, boilers and district heat were used more in larger buildings, while packaged heating units were used more in smaller buildings.

Information on cooling equipment for educational facilities is presented in Figure 4-9. Reference to the figure reveals that packaged air-conditioning units and central chillers were the most widely used type of cooling equipment. However, the two most widely used types of cooling equipment showed significant differences in use by size of building. Packaged air-conditioning units showed relatively greater use in the smallest educational facilities. Central chillers were used primarily in the largest buildings. That equipment type cooled more than 40 % of the combined floorspace of the three largest size categories, but less than 5 % of the combined floorspace of the three smallest size categories.

Information on six types of lighting equipment is summarized in Figure 4-10. The six types of lighting equipment are incandescent, standard fluorescent, compact fluorescent, high-intensity discharge, halogen, and other. Standard fluorescent lighting fixtures were found in nearly all educational facilities (more than 80 % of all floorspace). Incandescent lighting was also widely used (around 60 % of all floorspace). The three newer kinds of lighting technology, high-intensity discharge, compact fluorescent, and halogen, were used primarily in larger educational facilities.

Figure 4-8. Heating Equipment Usage in Educational Buildings by Building Size Category

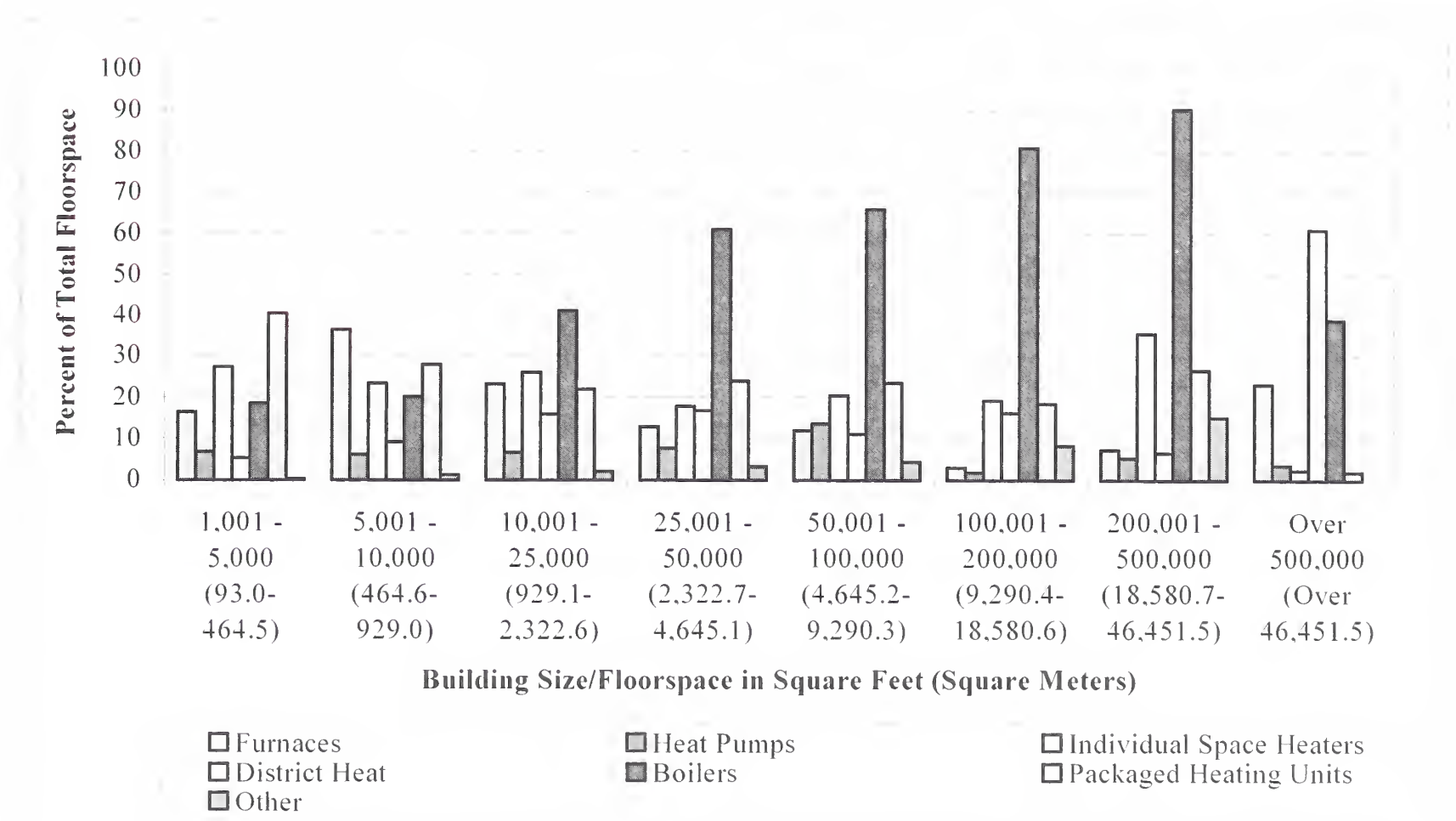


Figure 4-9 Building Cooling Equipment Usage in Educational Buildings by Building Size Category

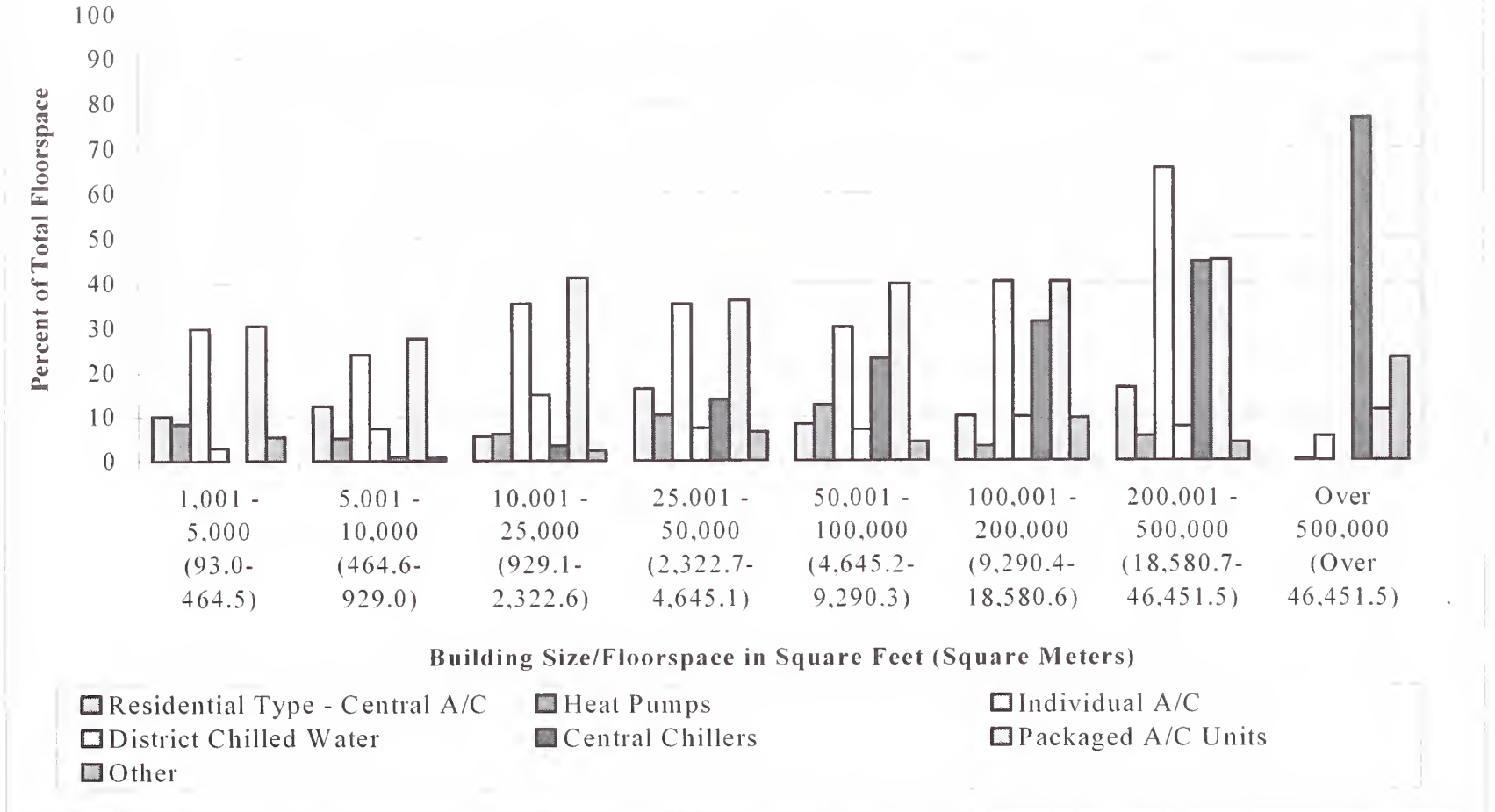


Figure 4-10. Building Lighting Equipment Usage in Educational Buildings by Building Size Category

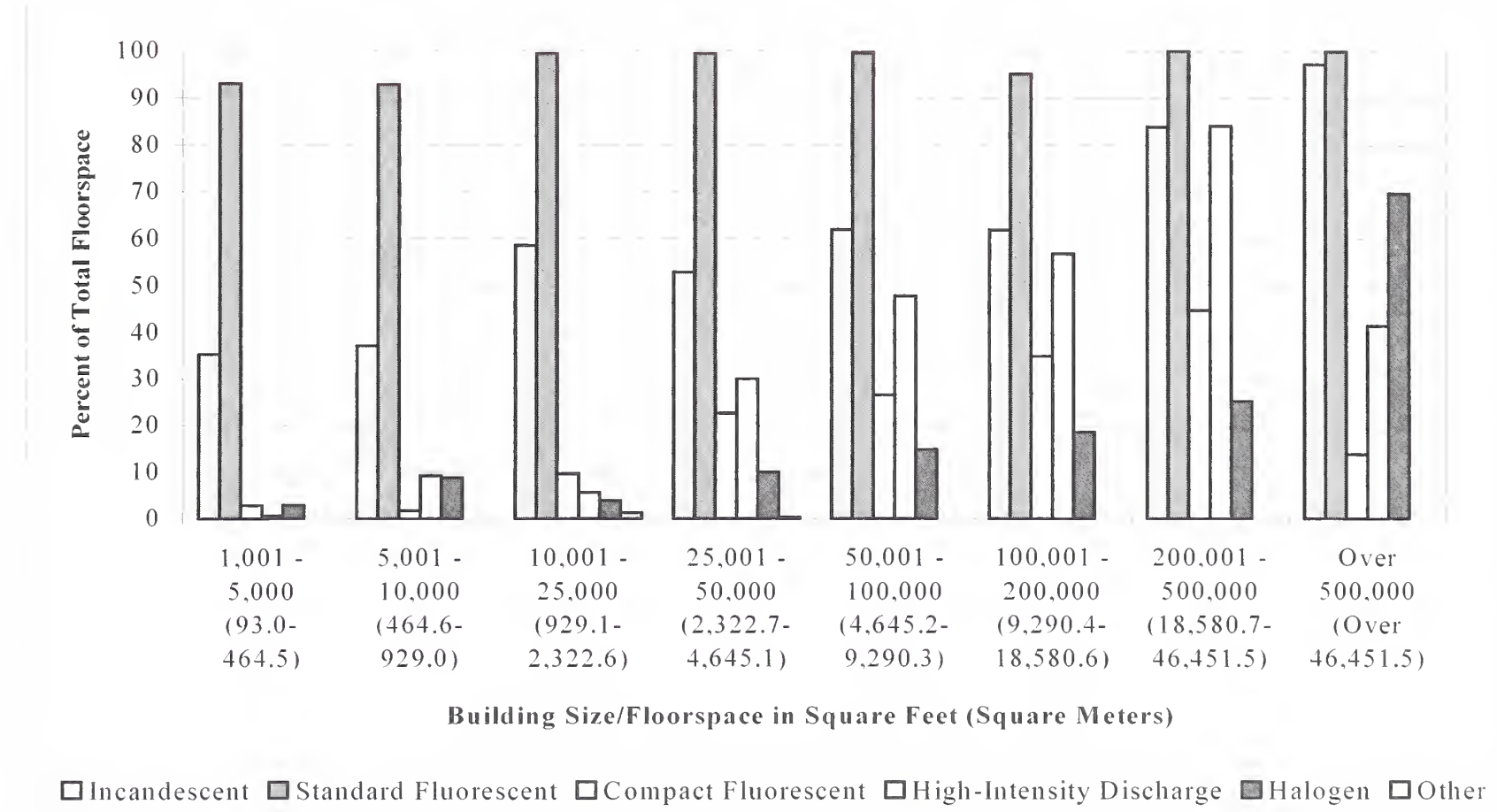


Figure 4-11. Educational Facilities Shell Conservation Features by Building Size Category

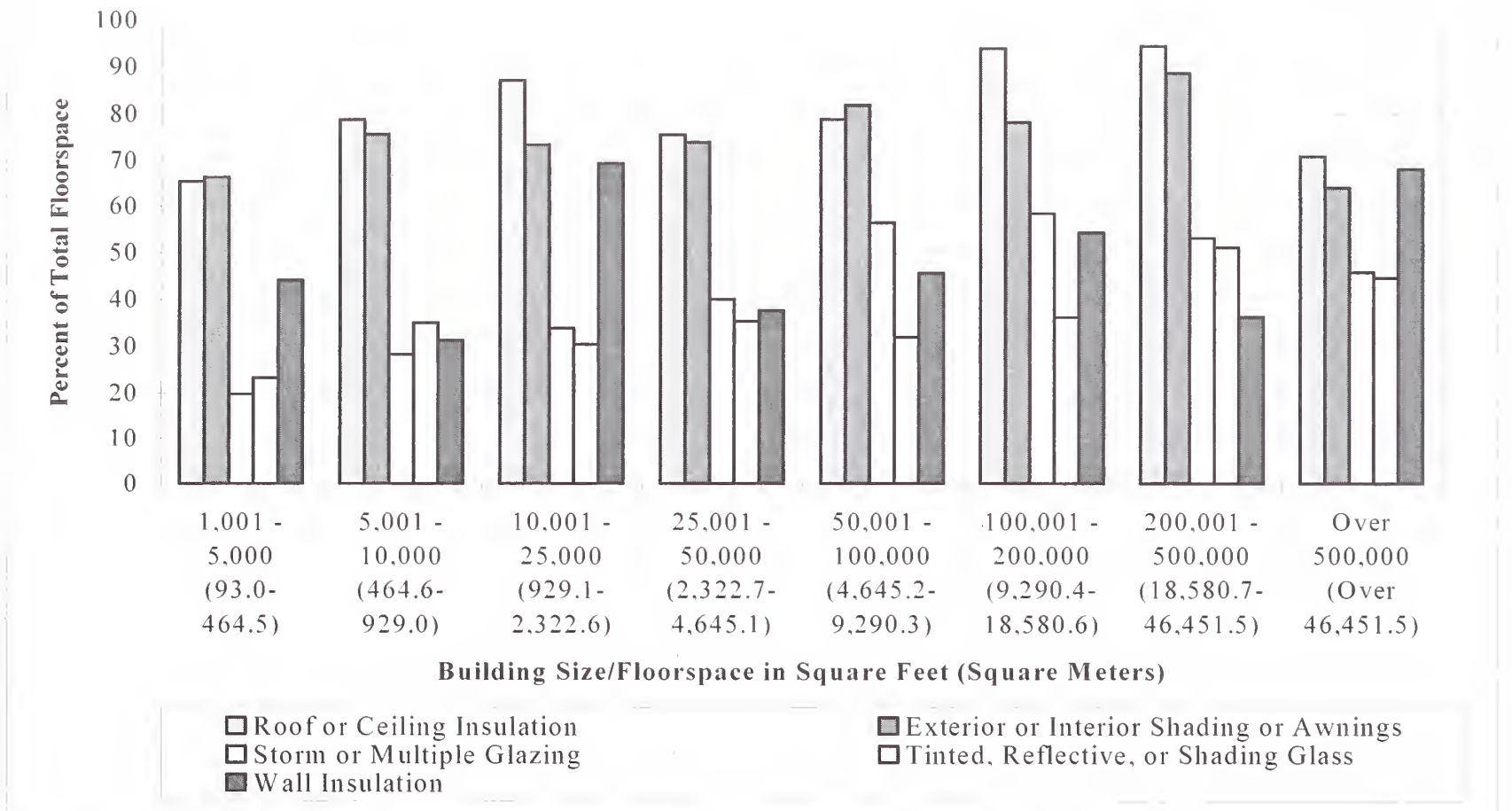


Figure 4-12. Educational Facilities HVAC Conservation Features by Building Size Category

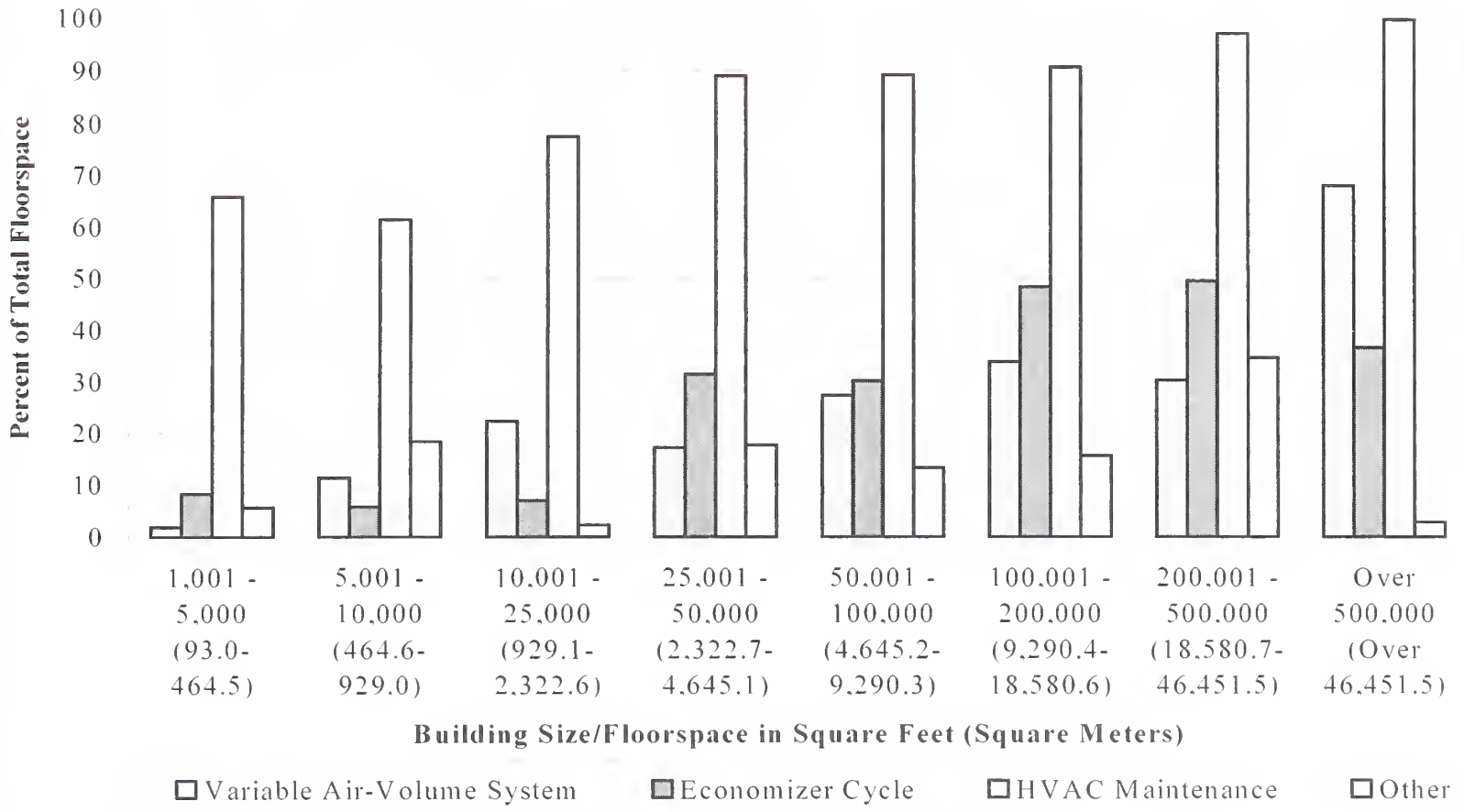


Figure 4-13. Educational Facilities Lighting Conservation Features by Building Size Category

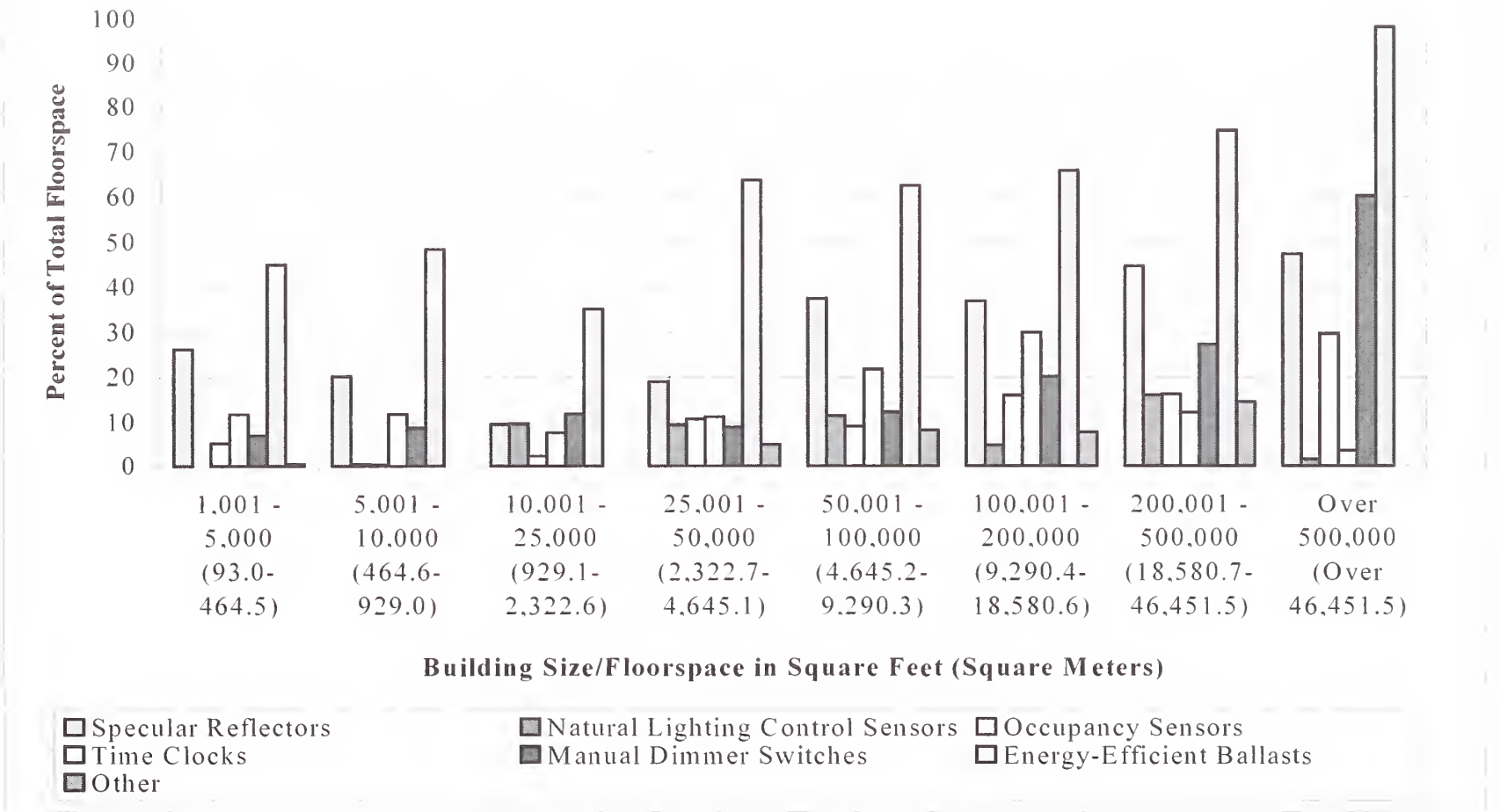


Figure 4-11 summarizes information on building shell conservation features. Figure 4-11 shows that most educational facilities had some type of building shell conservation feature. The feature most often found was roof or ceiling insulation; utilization of roof or ceiling insulation ranged from 70 to 90 % of total floorspace within each size category.

Figure 4-12 summarizes information on HVAC conservation features. Comparison between Figure 4-11 and Figure 4-12 shows that HVAC conservation features were, in general, less common than building shell features. HVAC maintenance, the most widely practiced of the HVAC conservation features, was performed in about 80 % of the floorspace. For the five largest size categories, HVAC maintenance was performed in 90 % or more of the floorspace.

Reference to Figure 4-13 reveals that a significant percentage of educational facilities floorspace employed some type of lighting conservation feature. The most widely used lighting conservation feature was energy-efficient ballasts. About two-thirds of educational facilities floorspace was covered by energy-efficient ballasts. Comparisons between Figures 4-11, 4-12, and 4-13 show that both HVAC and lighting system conservation were more often found in larger educational facilities.

4.3 Summary of Baseline Measures for Educational Facilities

This section summarizes the baseline measures for educational facilities that are presented in Sections 4.2.1, 4.2.2, and 4.2.3 of this document. These measures are presented in Table 4-7.

The table is organized to serve as a quick reference; it includes a brief description of each measure, the year for the data, the value of the measure in dollars per m^2 (per ft^2), and the source of the data. Two sets of summary OM&E measures are presented first—one for K-12 facilities and one for college and university facilities—followed by a more detailed set of measures.

Table 4-7. Summary of OM&E Baseline Measures for Educational Facilities

DESCRIPTION	YEAR	BASELINE	SOURCE
OM&E: K-12 Facilities	1996	$35.74/m^2 ($3.32/ft^2)	AS&U
OM&E: College & University Facilities	1996	$37.78/m^2 ($3.51/ft^2)	AS&U
Average Custodial (Cleaning) Cost	1993-1994	$9.81/m^2 ($0.91/ft^2)	APPA
Average Grounds Cost	1993-1994	$2.96/m^2 ($0.28/ft^2)	APPA
Average Solid Waste Disposal Cost	1993-1994	$0.56/m^2 ($0.05/ft^2)	APPA
Average Hazardous Waste Disposal Cost	1993-1994	$0.40/m^2 ($0.04/ft^2)	APPA
Average Security Cost	1993-1994	$3.81/m^2 ($0.35/ft^2)	APPA
Average Building Maintenance Cost	1993-1994	$9.63/m^2 ($0.90/ft^2)	APPA
Average Electricity Cost	1993-1994	$10.61/m^2 ($0.99/ft^2)	APPA
Average Gas Cost	1993-1994	$3.54/m^2 ($0.33/ft^2)	APPA
Average Water and Sewer Cost	1993-1994	$0.43/m^2 ($0.04/ft^2)	APPA
Sum of Major Fuel Expenditures: All Educational Facilities	1995	$9.90/m^2 ($0.92/ft^2)	CBECS

5. Summary and Suggestions for Further Research

5.1 Summary

The Construction and Building Subcommittee of the National Science and Technology Council is developing baseline measures of current construction industry practices and measures of progress with respect to each of the seven National Construction Goals. The seven National Construction Goals are concerned with: (1) reductions in the delivery time of constructed facilities; (2) reductions in operations, maintenance, and energy costs; (3) increases in occupant productivity and comfort; (4) reductions in occupant-related illnesses and injuries; (5) reductions in waste and pollution; (6) increases in the durability and flexibility of constructed facilities; and (7) reductions in construction worker illnesses and injuries. This document provides a detailed set of baseline measures for National Construction Goal 2 (reductions in operations, maintenance, and energy costs) for educational facilities. As such, it describes data sources, data classifications, and the metrics used to develop the baseline measures.

Chapter 1 provides background information about the project, its purpose, and scope. Chapter 2 introduces the National Construction Goals and describes how a well-defined set of metrics is used to develop the baseline measures. Chapter 3 provides an overview of the construction industry. The overview provides the context within which the baseline measures for educational facilities are developed. Chapter 4 presents the baseline measures for educational facilities.

Extensive use of charts and tables is made throughout this document to illustrate the process by which the baseline measures were developed. Sufficient data have been collected to establish baseline measures for OM&E costs for educational facilities. However, the level of detail of the baselines is highly variable, depending on data availability.

5.2 Suggestions for Further Research

The work for this document uncovered areas of research that might be of value to government agencies and private bodies who are responsible for the operations and maintenance of educational facilities. These areas are concerned with: (1) additional data collection; and (2) evaluation of progress toward achievement of National Construction Goal 2.

The Commercial Buildings Energy Consumption Survey (CBECS) provides a wealth of information on educational facilities. The CBECS micro-data files proved invaluable in establishing the characteristics of educational facilities. Unfortunately, the CBECS micro-data files do not provide a means for separating K-12 facilities from college and university facilities. Thus, the characteristics presented in this document are for the educational sector as a whole rather than for K-12 facilities or college and university facilities, respectively.

If such data were collected and made available, it would result in a much better understanding of the characteristics of both types of educational facilities (i.e., K-12 and college and university). It is important to note that the 1995 edition of the CBECS questionnaire contains the type of information needed to distinguish among different types of educational facilities.[28]

Having such detailed information would prove of value beyond measuring energy-related characteristics and expenditure patterns. For example, an expanded CBECS information resource represents an opportunity to measure a particular facility's performance against national characteristics for a similar type of *actual* facility. This information would also prove of value in establishing prototypical facilities from which non-energy-related estimates for operations and maintenance costs can be derived and used as metrics against which an actual facility's performance could be measured and evaluated.

Finally, in order to be able to measure progress toward National Construction Goal 2, periodic reports need to be produced which re-visit the same data sources used to generate the baselines, and refine or expand the original baselines as necessary to meet the changing needs of the stakeholders in the educational sector.

[28] The types of educational facilities covered in the CBECS questionnaire include: preschool, elementary, junior high, senior high, college or university classrooms/laboratories, and vocational school.

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